JOURNAL

OF THE

Association of Engineering Societies.

St. Louis. Minneapolis. Pacific Coast. Louisiana.
Cleveland. St. Paul. Detroit.
Toledo. Boston. Montana.

CONTENTS AND INDEX.

VOLUME XXXVIII.

January to June, 1907.

PUBLISHED MONTHLY BY

Fred. Brooks, Secretary of the Board of Managers of the Association of Engineering Societies.

31 Milk Street, Boston.

CONTENTS.

VOL. XXXVIII, January–June, 1907.

For alphabetical index, see page v.

No. 1. JANUARY.

No. 2. FEBRUARY.

No. 3. MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 6. JUNE.

INDEX.

VOL. XXXVIII, January–June, 1907.

ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVIII. JANUARY, 1907. No. 1.

FIRE PROTECTION ENGINEERING.

BY GEORGE VELTEN STEEB.

[Read before the Civil Engineers' Club of Cleveland, November 13, 1906.]

FIRE Protection Engineering, upon which I have been asked to speak to-night, is a natural evolution consequent upon the enormous waste by fire; for, while we are told that there can be no absolute destruction of matter, yet when we realize that during a period of twenty-one years from 1885 to 1905 inclusive, over $1 750 000 000 of property has "gone up" in smoke and flames in the United States alone, and been absolutely destroyed as far as its original purposes in the economy of the country are concerned, and that the smoke and flames produced have not served any useful purpose to mankind, and that the replacing of this property does not augment values, conditions, structures, stocks and other materials, and withdraws from other purposes vast sums of money, we must confess that in some respects matter is destructible. In consequence of this great destruction of values but one thing presented itself to the insurance interests other than practically prohibitive rates for insurance, and that was how best to conserve the interests of mankind at large by preventing the necessity of the duplication of man's labors on account of fires; and this gradually, through a long period of years, resolved itself into the technical subject of fire protection. The first step in the evolution consisted of inspection work directed only toward the modification of the common and inherent hazards, and was conducted by individual companies through non-technical men as a general rule. This was followed by inspection work in the interest of groups of companies

for the purpose not only of modifying the common and inherent hazards, but of eliminating all possible hazards, this work being done by a few technical men in specific branches and by men more or less trained in the general work by experience in the field only. Later developments have resulted in the organization of a national association of all persons interested in the science of fire prevention and fire protection, which takes up the modification and elimination of all hazards, proper construction and fire prevention and protection as a science, standardizes the various subjects specifically and formulates rulings on them which are the accepted standards in the United States and Canada, this work being done by technical men on specific subjects, by technical men trained in the inspection work, by thorough investigation and experimental work, by the application of the various rulings, by analyzing statistics of fire losses from particular causes, etc.

Fire protection engineering reaches far beyond the question of the loss ratio to fire insurance companies; it upbuilds the financial stability of the community and of the individual, for in a community subject at all times to a Chicago, Boston, Baltimore, Toronto or San Francisco conflagration, there exists the possibility of the ruin of the municipality as an important factor in the commercial world, the financial ruin of many an individual and firm and corporation, and a serious retardation of the material progress of the community for a considerable time; and in many indirect as well as direct ways the destruction of the manufactories, commercial interests and homes of citizens is of far-reaching consequence to a municipality. The interests of the community and of the individual are as much conserved as are the interests of the fire insurance companies; for, besides adding to their financial credit, a superior class of construction and protection not only presents a more esthetic appearance and stable condition, but reduces outlay, especially the items of repairs and insurance, by its greater durability and resistance to fire reduction possibilities.

Fire insurance engineering not only seeks the best methods for the extinction of fires, but seeks to eliminate or at least reduce to a minimum their causes, to provide methods of confining a fire to a unit (whether the unit be a block of buildings, a single building, a section, a room or a closet), and to reduce the possibilities of large losses; it involves construction, the reduction and elimination of common as well as inherent and external hazards, fire-fighting apparatus and appliances for the individual plant and

the municipality, and the standardization of construction and materials and installations; and it is so far-reaching as to involve the application of (and in many cases an intimate knowledge of) chemistry, architecture, construction, civil, mechanical, hydraulic and electrical engineering, processes of manufacturing and materials used in manufacturing; in fact, one may well say that there is no class of technical work into which it does not at one time or another enter.

To best explain what fire protection engineering is, is to give an idea as to what it has accomplished and what it is doing, for, covering such a wide range of scientific, technical and ordinary subjects as it does, it is impossible to "lump" the various ramifications of investigations, experiments, rulings and standards under one heading, as this would give but an indefinite and confused idea of this profession; therefore, in considering the individual subjects which I shall touch upon, I shall, in a general way, endeavor to indicate the results that have been accomplished, and point out how the work is being carried on, and how and where the standards and rulings are made, for this is an exact science, governed by rules and standards based on experiment, experience, investigation and statistics.

Wherein fire protection engineering is applicable can be illustrated by a view of the *general* and the *specific* propositions involved. For instance, consider the application of fire protection engineering to a building or a group of buildings of a single plant from its inception to its completed condition as an occupied property.

General propositions follow.

Preliminary: Specific standards are applicable to the architects' plans, whether for a "fireproof," "mill" or ordinary construction, a theater or a car barn, in respect to thickness of walls, subdivisions, fire breaks, types and construction of fire doors and shutters or wired glass for the protection of individual sections from each other or from surrounding buildings, etc.; and to construction in respect to the character, quality and strength of bricks, mortar, cement and concrete, masonry, lumber, carpenters' work, wrought and cast iron, steel and cast steel, etc.

Installation of permanent furnishings: Lighting and heating, both as to construction and location of artificial and natural gas, gasoline gas, acetylene gas, vapors for lighting, electric lighting, steam pipes and stoves, are all covered by rulings and requirements, and receive direct attention from inspectors or examiners.

Fire extinction appliances and apparatus: The character of the building or group, its location, its occupancy, etc., determine the question whether it will be necessary to have a fire pump, outside mains, yard fire hydrants, outside hose, outside hose houses and equipment, inside standpipes and hose, private fire brigade, automatic sprinklers, outside open sprinkler heads, chemical extinguishers, water pails and casks, blankets, sand, steam jets, automatic fire alarm systems, etc.; also the location and size and quantity or number of each of these.

Equipment of the building for its occupancy: There are specific rulings as to construction, location and installation of dry kilns, shavings vaults, waste picker discharge rooms, grain and other dryers, grain elevator heads, blower systems, fuel oil systems, gasoline and gas engines, supplying oils and benzene to mixers, systems for storing volatile fluids, automatic journal alarm systems, distance of stacks, furnaces, cupolas and other heat-producing appliances from combustible materials, metal cans for waste and for ashes and rubbish, protection of shaft and belt openings in walls, care and handling of benzene, gasoline and other volatile fluids, board scrapings, shavings, sawdust, polishing wheels, dust and fiber, packing materials, chemicals, and as to watchmen and watchman's time detectors, and so on to an almost unlimited extent,— all subjects of investigation at each risk by the inspectors and engineers.

Specific propositions may be presented by reference to the more important points of the rules and requirements promulgated and accepted as standard.

Construction: " Fireproof,"—strength, character and proper protection of metal members, cutting off of vertical openings, etc.; " mill " construction, avoidance of all concealed spaces and vertical openings, walls, cornices, floors, posts, stairways, elevators, flues, partitions, timbers, methods of setting timbers in walls and for floor supports, divisions of buildings, etc.; theaters, — proscenium wall construction, fireproof curtains, skylights, fly galleries, stairs, etc.; car barns for electric railways, materials, divisions, etc.; ordinary hollow space type of construction, — chimneys, sheathing, cornices, skylights, protection of vertical openings, etc.; generally, — fire doors and shutters, wired glass and the construction of frames for wired and prism glass used as a fire retardent, and almost all points in construction as to types and materials and parts, etc.

Permanent furnishings: gasoline, vapor, gas lighting machines, lamps and systems, kerosene oil pressure systems, acety-

lene gas machines and storage of calcium carbide, electric wiring and apparatus, electrical fittings, gasoline stoves, steam pipes, boilers, hoods for cooking ranges, boiler stacks.

Fire appliances and apparatus, for construction as well as installation of steam fire pumps, electric fire pumps, rotary fire pumps, steam pump governors and auxiliary pumps, hydrants for mill yard use, 1.25 in., 1.5 in. and 2.5 in. unlined linen fire hose for use inside buildings, 2⅝ in. cotton rubber lined hose for mill yard use, hose houses for mill yards, private fire departments, sprinkler equipments (automatic and open systems), stationary chemical fire extinguishers, carbonic acid gas, hand fire extinguishers, fire pails, sand pails, signaling systems used for the transmission of signals affecting the fire hazard, auxiliary fire alarm systems, etc.

Equipment of the risk for its occupancy: automatic journal alarms, gas and gasoline engines, storage and use of fuel oil and for the construction and installation of oil-burning equipment, systems for storing 250 gal. or less of fluids which at ordinary temperature give off inflammable vapors, construction and installation of grain dryers, coal gas producers (pressure and suction systems), waste cans, ash cans, refuse barrels, safety cans for benzene and gasoline, electric fire alarm thermostats, etc.

In the application of fire protection engineering to the municipality there are rules and specifications for the protection of a building against its neighbors by fire walls, fire shutters, wired glass, etc., and for water supplies, capacity of reservoirs, standpipes and pumps, sizes of mains, character and quality of the fire-fighting apparatus, etc. At this point it seems well to call attention to some specific features in one of the latest phases of fire protection engineering, that is, the investigation and listing of needed improvements in public water service, fire alarm service, fire department service and building codes, as now being conducted by committees of experts under the direction of the National Board of Fire Underwriters. Cleveland has been lately investigated by such a committee and the defects found in the various departments have been listed, and proper remedies for undesirable conditions have been pointed out, and it will be regrettable if the more important of these suggested improvements are not acted upon at once and carried out in spite of any false pride or sentiment on the part of any official or citizen, for they are based upon the opinion of men particularly well qualified to pass upon such subjects, and are for the best interest of the city, and are not an excuse to increase rates of insur-

ance, as some ill-informed citizens have stated. Another local subject is the laying of high-pressure mains at this time for fire-fighting in our city, and we can only hope that the work will be supplemented by the proper installation of an adequate high-pressure pumping plant, for while the present proposition is of great value, still it can only be considered a "makeshift," and not an adequate, high-pressure water system. I trust that you gentlemen who have the interest of this city at heart will in all ways bring your influence to bear upon the carrying out of the improvements and extensions referred to.

The rulings and requirements in use are not the production of the fire insurance interests alone, for in the committees appointed to formulate them are representatives identified with the specific subjects treated of; and while they are put forth by the National Board of Fire Underwriters, they are the results of the investigations, tests, statistics and experience of the National Board of Fire Underwriters and its expert committees, of the National Fire Protection Association, of the individual fire insurance companies and of the manufacturers and installers of the various appliances, etc. As the rulings are determined upon by the National Fire Protection Association, a glance at its *personnel* will not be amiss. It is composed of persons interested in the science and in the improvement of methods of fire protection, and has 52 active members, consisting of insurance boards, insurance associations, national institutes, societies and associations interested in the protection of life and property from losses by fire (amongst whom we find, besides the insurance interests, the American Institute of Architects, American Society of Mechanical Engineers, American Warehousemen's Association, American Water Works Association, International Association of Fire Engineers, National Electrical Contractors' Association), 724 associate members who are individuals engaged in the fire insurance business and individual members of the organizations represented in the active membership, and 267 subscribing members who are individuals interested in the protection of life and property against losses by fire, and in this class any one is eligible. It is from this membership that committees are formed, and it is after discussing the conclusions of these committees at the annual meetings of the Association, in open meetings, that the rules and requirements are finally formulated and promulgated; hence the faults in construction and equipment, the causes of fires, etc., as found by the insurance interests through inspections and statistics, are thoroughly and

scientifically considered and discussed and passed upon by all the interests involved in any one branch of the subject.

While the rules give definite instructions as to the materials, sizes, general character of parts for construction of standards and types of fire pumps, hydrants, hose, chemical extinguishers, gasoline and acetylene gas machines and lamps, etc., they are so drawn as not to interfere with the individuality of any special design which covers the points named in the rules in a correct manner; they simply embody the essential features of construction of the various apparatus and leave it to the manufacturer to make his own particular form and design.

The investigation and testing of fire resisting materials, electrical devices, fire extinguishing appliances and other devices and materials, are conducted in a specially constructed fireproof building known as the Underwriters' Laboratories, under the supervision of members of the National Fire Protection Association, and unless the specifications for construction and workmanship are complied with and the tests show certain conditions and results, the device or material being investigated and experimented upon or tested will not receive the approval of the Association, cannot be listed as an approved device or material and will not be accepted in practice. Besides this laboratory there are several others employed in the same class of investigations and tests, but these latter laboratories have not authority to approve or accept devices, etc., for the general insurance interests.

While I have not made this paper as specific as some of you gentlemen would desire, it has only been the necessity of confining myself to a reasonable length of time that has prevented a more extended and comprehensive presentation of some of the various phases, but I trust that I have made it clear that in fire protection engineering we have no hesitation in tackling common or inherent or exposure hazards, construction, installation and protection, whether it takes us "way up" or "way down"; that there is nothing within its province which is either too large or too small for consideration; that the conclusions arrived at are based on well-defined premises, with thoroughness and a full grasp of the subjects involved; and that this is a profession which redounds to the welfare of all people.

DISCUSSION.

DR. MILLER. — Mr. Steeb has presented in a very interesting manner facts which show that fire protection has been

studied very thoroughly and systematically by the underwriters, and their rulings are no doubt sufficient, but I wish that he had given us something more specific for the purposes of discussion.

Mr. Lane. — I would like to know just what Cleveland is doing in regard to the high-pressure system.

Mr. Steeb. — A couple of years ago the question of high-pressure water service was taken up in the city and a plan was made for protecting all the district from East Ninth Street down to the river, and I don't know how far the pipes went south, but all the way to the lake and then running out to the manufacturing district along the lake. This was brought up to the water works department, and they determined that the outlay of money would be too great to undertake such a system, but by insistence and eliminating all the lines running along the lake east from East Ninth Street we at last got them to agree to put in a system which will eventually make East Ninth Street the center of the high-pressure system. There is a 30-in. pipe being laid in East Ninth Street, which we hope ultimately will extend down to the Kirtland Street pumping station. From this 30-in. main, which is run through East Ninth Street, the 20-in. and 10-in. and various sizes pipes are now laid and being laid in the district between the lake, East Ninth Street and the river. There are two extensions which run down to the river and it is proposed in case of fire to attach fire tugs. The system is rather inadequate. It will be readily seen that it will be a makeshift, but it can also be seen that it will give us protection through the commercial district.

Mr. Lane. — I notice in laying the pipes on Superior Street there were some 3-in. pipes laid on top of the fire pipes. Did they have anything to do with the high-pressure service?

Mr. Steeb. — I don't know. The smallest pipe to be put in are two connections over towards East Sixth Street, and for a short distance there will be two sections of 4-in. pipe. This is the smallest pipe.

Dr. Miller. — It is possible some of the members of the city water works department are here as guests this evening, and we should be glad to hear from them or from any other members of the club.

Mr. Lane. — Will the entire amount of water received by the 30-in. come from the fire tug, or will the Kirtland Street pumping station do something?

Mr. Steeb. — At this time only the fire tugs.

Mr. Lane. — How many standard streams is that equal to?

Mr. Steeb. — I think we figured with the tugs that we could get 10 standard streams from 6 fire tugs.

Mr. Carroll. — I have been requested to ask Mr. Steeb regarding reënforced concrete building for mill stores as to their being absolutely fireproof.

Mr. Steeb. — No, sir, because we don't know what the concrete is made of and we don't know what the cement is made of. We don't know the mixture and how long it has stood. We have a committee of the National Fireproofing Association, and that committee made a report at the last meeting, but they are checking the subject up further. They have no statistics on concrete building, and while they are nominally fireproof, we cannot say that they can be depended upon.

Mr. Carroll. — I would like to ask Mr. Steeb's opinion as to the merits of the different kinds of hollow tile used in construction, viz., hard, semi-porous and porous.

Mr. Steeb. — We have no definite conclusions on them either. You see tile construction as we have it to-day only dates back a very few years and we cannot arrive at any definite conclusions on this experience. Our rulings are based on statistics and experience, and no insurance company takes its statistics as being worth anything unless it includes 7 to 10 years. We have no experience on this class of construction for that length of time. I have a case in mind of a coal mine lately. A hollow vitrified tile has been used for the construction of the power house. We had a fire in the mine the other day. The wall construction was hollow tile. There was a planking floor around the engines. There was a wooden roof with wooden sheathing. The roof burned and fell down, and the wall was badly cracked on the inside. The fire was not very large. There was a crack on the inside but none on the outside; simply an inside section of the facing was cracked. We have no real statistics. Take the cement and concrete blocks that are being made to-day. Any man can put up a two by four shack and get a little cement — it doesn't make any difference what kind — and he can get a little sand and make some tile block and build dwellings with them, and it is wonder that they don't fall down. There is no question but that they will fall down. Until you get a standard of mixture we can never have a standard for block.

Mr. Carroll. — In regard to mill-constructed buildings, I have been told that the board of underwriters will insure a mill-constructed building at a lower rate than one having a steel frame. Is this correct?

Mr. Steeb. — The types in each class are so varied it is hard for any one to state. You take a steel frame building, and if the members are not thoroughly protected, it is better to have a wooden frame building. The question of insurance rate has entirely to do with how each building is constructed. We have buildings here in this city that we call fireproof on which you can almost go and pick the tile off. You will find on the lower side of the I beams that they have thin pieces of tile. We find these conditions all through on account of poor covering to the metal member and also of the channelling of the fireproofing of the metal members for wires and pipes, and the covering of these channels with plaster on wire netting. In Baltimore a number of buildings were doubled up on account of this construction. As to mill construction, there is not a mill-constructed building anywhere in this section. There are a number of them in the East and quite a number now of new cotton mills in the South, but we have no mill-constructed buildings in this section. Because a man uses heavy timbers and solid post and has a double floor and has no hollow space in his walls, he says he has a mill-constructed building. In a mill-constructed building there are absolutely no openings in the floors.

Mr. ——.— I have seen it stated that it is impossible to construct a fireproof building. What do you think of it?

Mr. Steeb. — I don't know. It's hard to answer. If you will properly protect all metal members on bridge-constructed buildings, you can get a fireproof building, but you have to take the stairways out and the hatchways out, and would have to have the entire construction of steel. What would burn in the building would have to be eliminated. Because we call a building fireproof, we don't mean that the contents would not burn. I don't think we have any building that we can call absolutely fireproof. There is talk now of putting up glass buildings.

Dr. Miller. — Mr. Steeb had occasion to refer to the fact that the fireproofing in Baltimore was not very good. I noticed the same thing in connection with the San Francisco buildings at close range several weeks ago; in many buildings that were supposed to be fireproof the fireproofing fell away, the beams softened and the whole building collapsed finally. I also saw Baltimore after the fire, but the destruction at San Francisco is much more complete. One cannot imagine the conditions there. In 5 square miles I believe there were only three buildings that were not burned. These are the United States Post-office, the United States Mint and the United States Custom

House. The post-office was cracked a little, but not seriously. The fire did but slight damage; there is no doubt that they were well constructed in the first place and were fairly well provided with fire protection. However, to see these three buildings standing, and all around for a distance of nearly a mile on all sides burned down, was a striking illustration that reasonably good construction and good care are worth while. At Stanford University many buildings were flat on the ground. Only the older buildings were uninjured; the new buildings were wrecks, and the reason for it appeared to be due to the very poor quality of cement, mortar or whatever held the stones together. They were made of soft stone, and I saw hundreds of cracks in the buildings and not one crack through the stone; always in the joint. In San Francisco I remember seeing two structures equally high, both of them made of brick, one flat on the ground and the other standing without a crack, which shows that one had good mortar and the other poor mortar.

Mr. Lane. — I have looked over several reports of the San Francisco disaster, with probably 1 500 photographs, and our speaker to-night has spoken about concrete, saying he did not know much about it, but every one of those reports claims that the concrete reënforced construction gave the best account of itself of any of the building systems that went through the San Francisco disaster, that buildings that were constructed this way stood the best. There are two things that may be of interest in regard to the San Francisco fire. In the first place, the first fire was probably a small affair, and would probably have died out if some one had not started a fire in a stove where the chimney had been destroyed by the earthquake. This is shown by the photographs. The photographs taken show very plainly the progress of the fire toward the water front, and then show this one building taking fire, and there are some 40 photographs showing the fire doubling back and taking in the greater area. Another interesting point is this: There was a factory building of tile and brick, fireproof construction, with a large window area. The earthquake took one section out of the upper story. One interesting thing is that the building was burned on three sides and passed the fire successfully on account of the fact that it had metal sash and wire glass and 5 or 6 of the men stuck to it and stayed inside and put the fire out with water from a big tank in the building.

Dr. Miller. — In regard to Mr. Lane's statement that the fire would have been under control, etc., and that the

conflagration would have been limited, I can give no information. My impression is that the fire started in many places. At the time I left San Francisco they had not started any new buildings; no doubt many designs had been made. During the past summer one of our members was in San Francisco designing new reënforced concrete buildings. There is a great demand for ordinary engineering work, but not very much demand for the highest grade of engineers.

Mr. Palmer. — Is granite considered a good material for a fireproof building?

Mr. Steeb. — No, sir. We don't allow granite if we can prevent it. We would not have granite coping on a brick pier in a building.

Mr. ——. — Would you have sandstone?

Mr. Steeb. — Sandstone is better, because when it is heated it does not disintegrate. We prefer to have no stone on it.

Mr. Carroll. — I have noticed in reading various engineering papers that there is a great deal of difference of opinion as to whether reënforced concrete is better fireproofing material than hollow tile, and I notice that the *Fireproof Magazine*, published by the hollow tile trust, in all cases, of course, states that hollow tile is a better fireproofing material than reënforced concrete. I have not had time to sift all of these articles down so as to satisfy myself as to which is the better. I would like to ask Mr. Steeb if he knows of any literature that is impartial and treats each construction on its merits.

Mr. Steeb. — The magazine you refer to, the *Fireproof Magazine*, is gotten out by the people manufacturing that material. Of course in reënforced concrete construction we have a whole building built of reënforced concrete, whereas in fireproofing it is only applied to steel members to keep them from giving way. The building is not built of fireproofing appliances. It simply is a protection, so there is no comparison between the two. As to whether a block would simply disintegrate either by age or by the amount of water or heat any faster than reënforced concrete, we don't know. We are making tests, but they cannot be compared because they are used in entirely different ways. The construction of reënforced concrete gives us a better building than any we have yet had.

Mr. Lane. — There is one thing that may be of interest, and that is that the Taylor-Wilson shops at McKees Rocks, Pa., built with the side walls of reënforced concrete and a big arch sprung over the entire building, have succeeded in securing a

lower insurance rate than any other building in the Pittsburg district.

Mr. ——. — I would like to ask Mr. Steeb this question: Given two steel frame buildings, one fireproofed with tile construction, the other fireproofed with concrete, which would be considered the better risk?

Mr. Steeb. — The only construction of that kind that we know of would not exactly apply to your question, because we have no absolute concrete protection to steel members. The nearest approach to it is by using wire netting and then using cement upon the wire netting. I don't know why it has never been used, but I presume other ways were found to construct a steel frame and then all the members were thoroughly enclosed with concrete. It has never been done because all that would really make reënforced concrete construction. Members are used instead of rods; it would make a very expensive construction, so there is no such construction. The nearest to it is using some netting and then using cement upon that.

Moved by Mr. Palmer and seconded by Mr. Neff that the Club extend its hearty thanks to Mr. Steeb for this very interesting paper upon this important subject. Unanimously carried.

[Note.— Discussion of this paper is invited to be received by Fred. Brooks, 31 Milk Street, Boston, by March 15, 1907, for publication in a subsequent number of the Journal.]

THE USE OF SUCTION GAS PRODUCERS FOR POWER PURPOSES.

By N. T. Harrington.

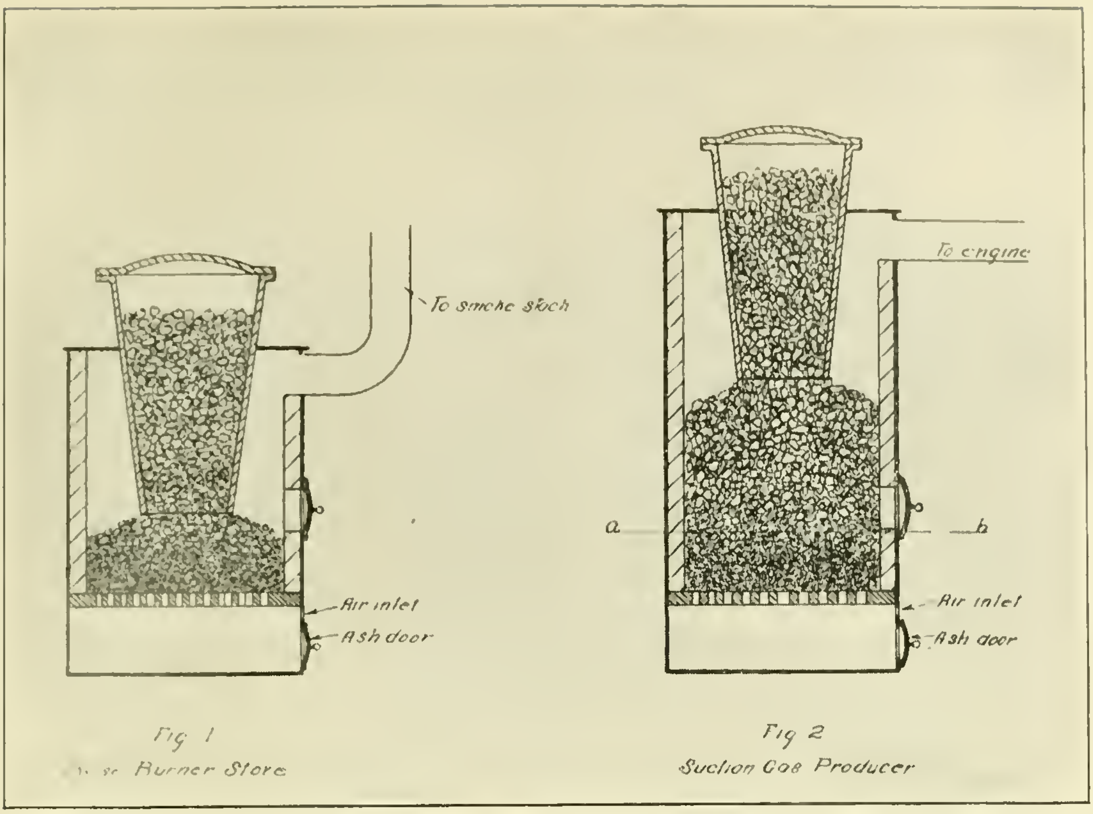
[Read before the Civil Engineers' Club of Cleveland, January 9, 1906.]

Below will be given a short description of a suction producer, a discussion of the different classes of work to which it is applicable, with performances under different classes of service, general comparison with performances of other types of prime movers, a discussion of the best type of producer gas engines and a few remarks on plant arrangement.

A suction gas producer may be considered as having been evolved from a base-burner stove. Let us suppose a base-burner stove like Fig. 1. It will be seen that this stove consists of a magazine thimble, a bed of fuel, grate bars to support the fuel, the body of the stove lined with fire brick, vent to the smokestack outside the thimble and outside the fuel, and ash door as well as door above the fire through which the fire can be seen.

The body of fuel which is burning in such a stove is usually from 8 to 10 in. deep. Air, which is admitted through the damper of the ash door, passes through the grates and is sucked up through the fire by the draft in the chimney and passes out to the smokestack. This air, in passing through the fire, combines with the carbon of the coal to make a practically complete combustion, the gases going to the stack as result of this combination being CO_2, N and a small amount of CO, or unburned gas. There will also be some trace of hydrocarbon gases which are distilled off from the coal in the magazine forcing their way down through it and up the outside of the thimble to the stack. These will vary in quantity depending on the amount of volatile matter in the coals. With anthracite coals the volatiles usually amount to less than 6.05 per cent. by weight.

It will thus be seen that, with a base-burner stove, practically all the gases are burned, and as the object of a stove, of course, is to furnish heat, the more completely these gases are burned to CO_2 the more efficient is the stove. There will always be unburned gas with a base-burner stove, inasmuch as it is impossible to have the exact amount of oxygen distributed through the fire uniformly at every point, where it should be present to combine with the carbon.



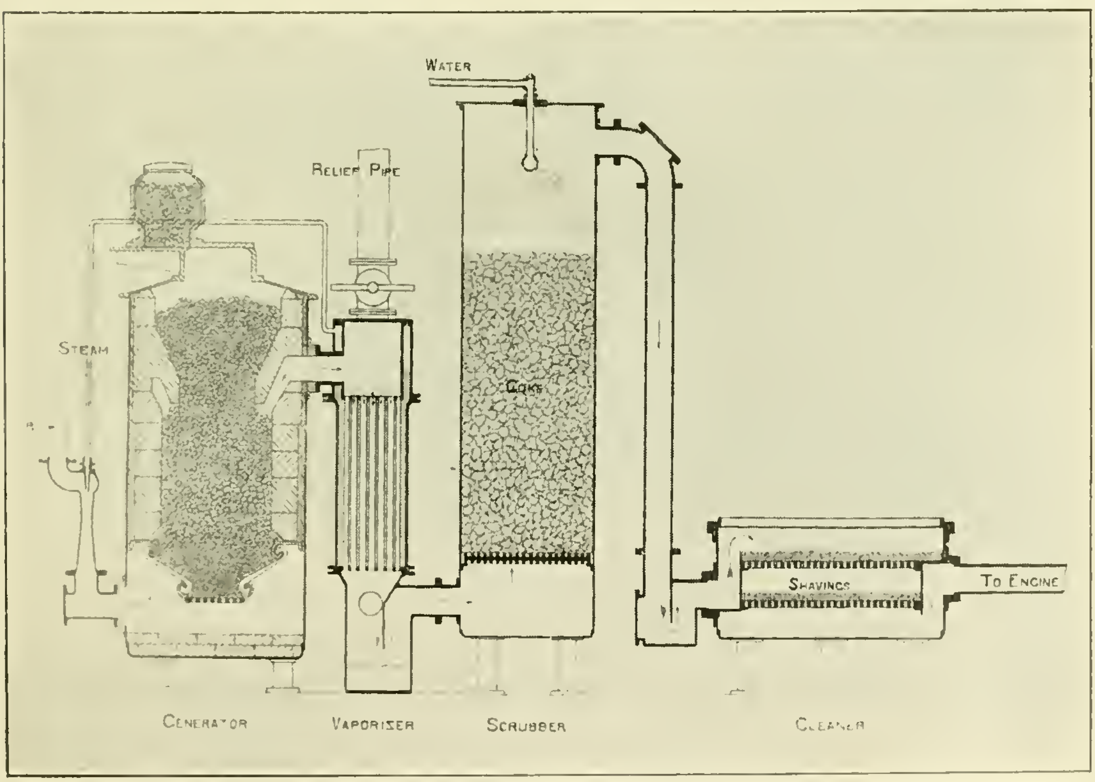


FIG. 3. ASSEMBLED PRODUCER WITH THE PIPE CONNECTIONS.

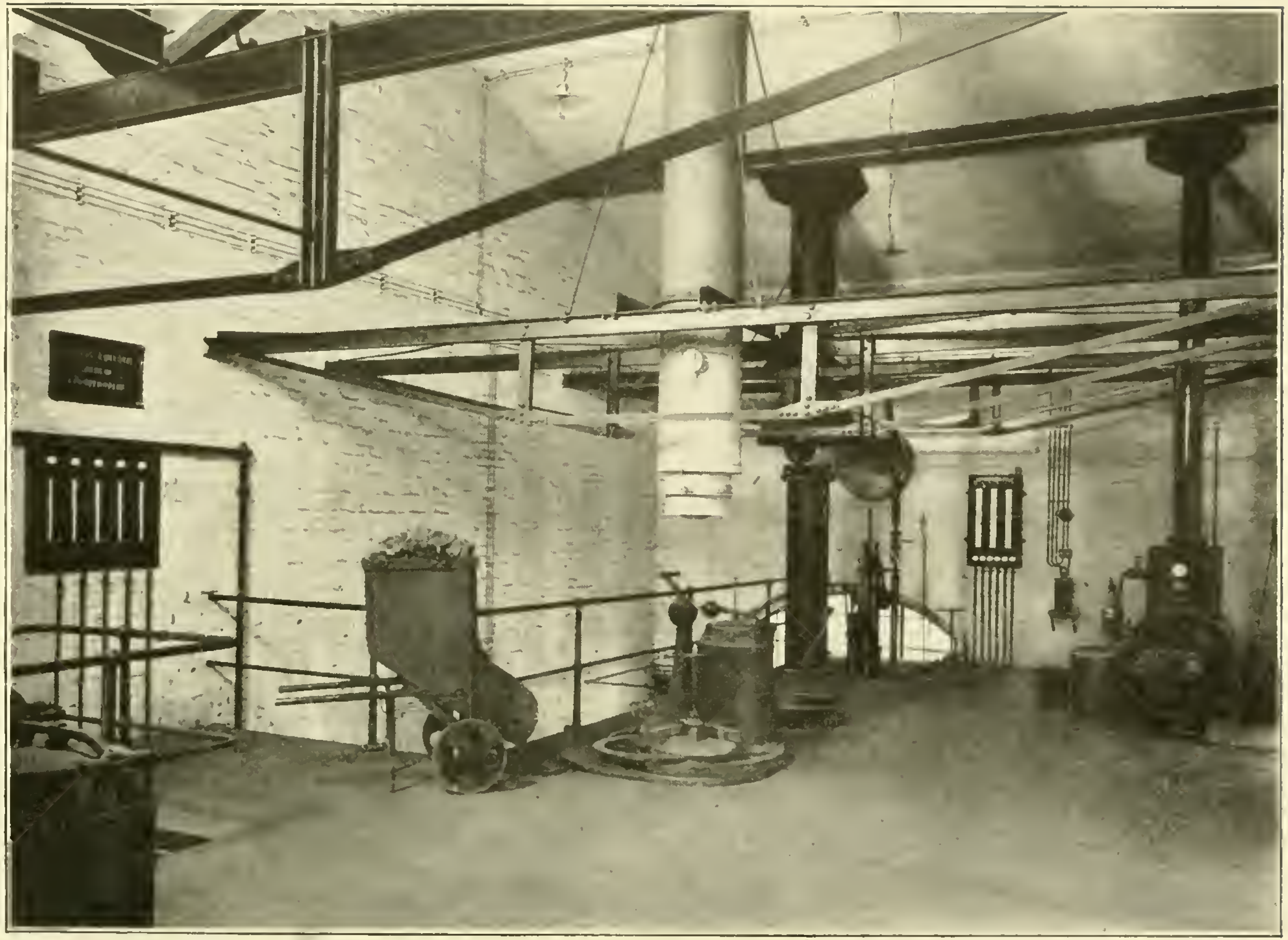


Fig. 4. Charging Floor. (600 H. P.)

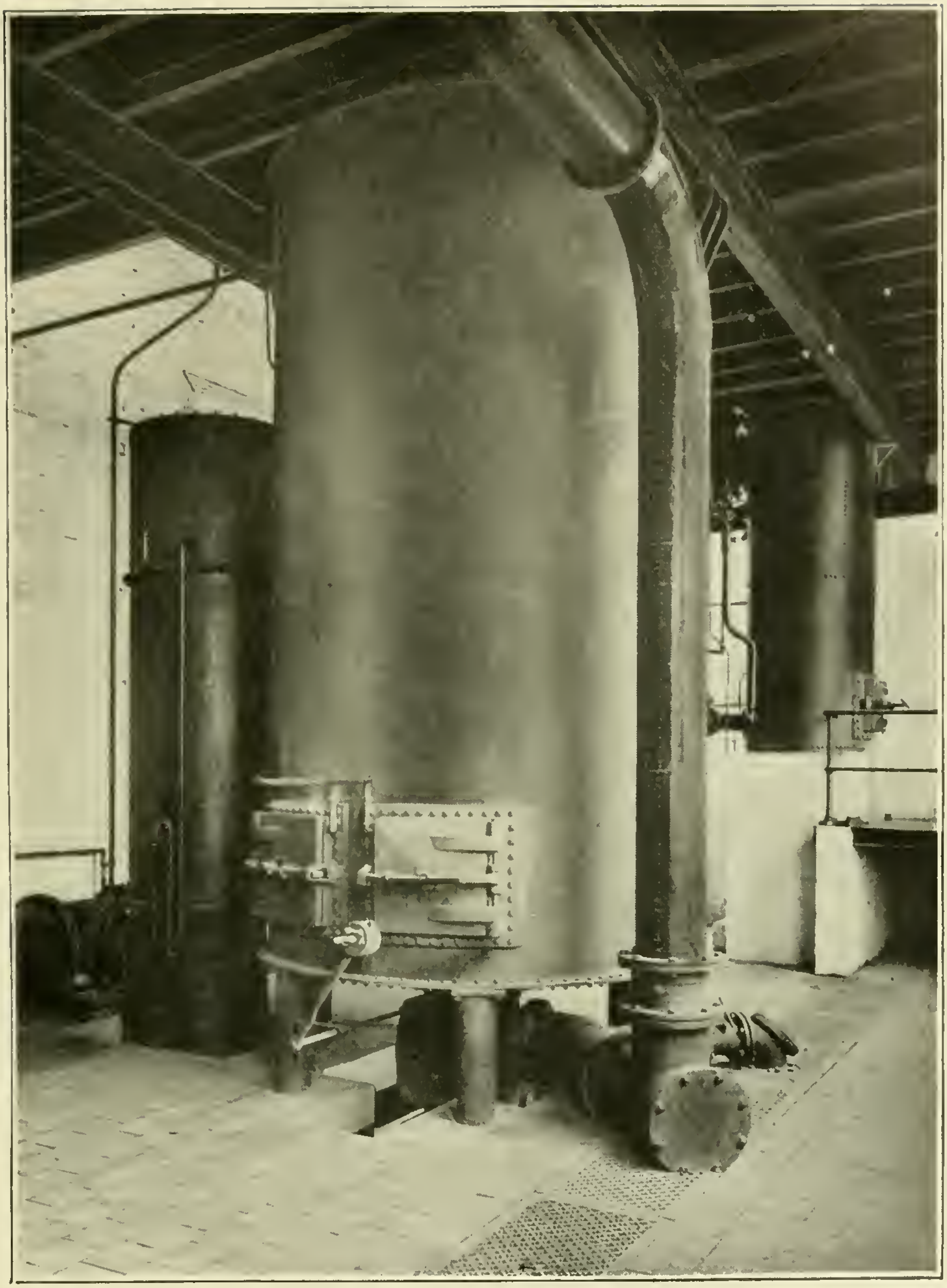


FIG. 5. 600 H.-P. GENERATOR.

Fig. 6. Scrubbers.

With this fire it will be found that oxygen is present as oxygen all up through the mass of burning coal even up to the top of the fuel bed, and the combustion is occurring from the bottom of the fire up to the top of the burning mass.

What is necessary to turn this stove into a gas producer? In a gas producer we have the equivalent of a smokestack, viz., the suction from the engine, to draw the air in through the fire and the gases out through the vent. We have the same grates, the same thimble, the same outer shell with lining, ash door and damper, the only difference consisting in the fact that the depth of the fuel body, in a suction gas producer, is increased over that of a base-burner stove, as shown in Fig. 2.

Why, then, should this slight difference in the depth of fuel body make all the difference between generating a combustible gas, as in the case of a gas producer, and making a completely burned gas, turning most of the heat value of the coal into sensible heat, as in the case of a stove?

The reason is that it is only possible to make combustion occur with ordinary low drafts up through 8 or 10 in. of the fuel body. In a stove, as we have seen, the fuel body is only this deep and, therefore, the gas comes off completely burned. With a producer, however, up to a zone *ab* (Fig. 2), which is about 8 in. above the grate, we have a resultant gas made up of CO_2 and N as the product of combustion. The heat generated by the formation of this gas is confined within the walls of the producer and heats the fuel above the zone *ab* to an incandescent temperature. The CO_2 gas must pass through this incandescent fuel to find its way out to the engine and, in passing through this fuel, each molecule of CO_2 gas will pick up an atom of carbon, thus forming two molecules of CO gas. This CO gas passes out through a pipe to the engine with the N brought by the air into the producer, forming a combustible gas which can be later burned in the engine. This would be a most elementary sort of a gas producer, and by filling any base-burner stove up with coal to a depth of about 30 in. above the grates, a gas could be formed upon which an engine could be operated.

In the actual development of these producers several things were found necessary. A double valve was imperative at the top of the magazine to prevent the drawing in of air while putting in coal. The magazine thimble had to be made of fire brick so that it would not burn. Some means were found necessary to keep the temperature of the fire low enough so as not to burn the grates or form clinker, the most objectionable of these last two

being the formation of clinker. It was discovered that by admitting steam, with the air going in underneath the grates, not only could clinkering be prevented and the grates kept cool, but an actual increase in the thermal value of the gas could be made. This being due to the fact that by breaking up the steam in the combustion zone, by means of high temperature, the hydrogen and oxygen of the steam could be separated, the hydrogen going through the fire, as hydrogen, to enrich the gas, and the oxygen, being pure oxygen, serving to supply some of that required for combustion and making necessary a smaller quantity of air.

As a result of this maneuver less nitrogen would be brought in and, as nitrogen is perfectly inert, any reduction of the nitrogen in the final gas would serve to increase its thermal value provided the amounts of the other elements remained constant.

Gas generated in a producer, without the use of steam, would have a thermal value of somewhere around 70 B.t.u. per cu. ft. By using steam with the air admitted to the fire, the producer gas generated will immediately have a thermal value of 135 to 140 B.t.u. per cu.ft.

The clinkering in the fire has been reduced at the same time the temperature in the combustion zone is lowered, owing to the heat abstracted by the steam, the reduction in the amount of clinkering being due to the fact that the temperature has been kept below the fusing point of the ash in the coal. The reduction in temperature in the combustion zone also tends to increase the life of the grates.

Gases, other than steam, have been used for this purpose, CO_2 being the one from which the best results have been obtained. A certain amount of CO_2, obtained from some external source, can be put through the fire without causing it to go out; this CO_2, being broken up in the incandescent zone, like that from the combustion zone, forms CO. The gas resulting from such a process, however, has a much lower thermal value than that formed by the use of steam.

In passing these cooling gases through the fire, some automatic device must be used to proportion the amount of cooling gas so added to the amount generated by the producer; that is, when driving an engine under variable load, at certain times a great deal of gas is generated from the producer and at other times very little. Thus it is necessary to alter the amount of cooling gas to prevent quenching the fire under light loads.

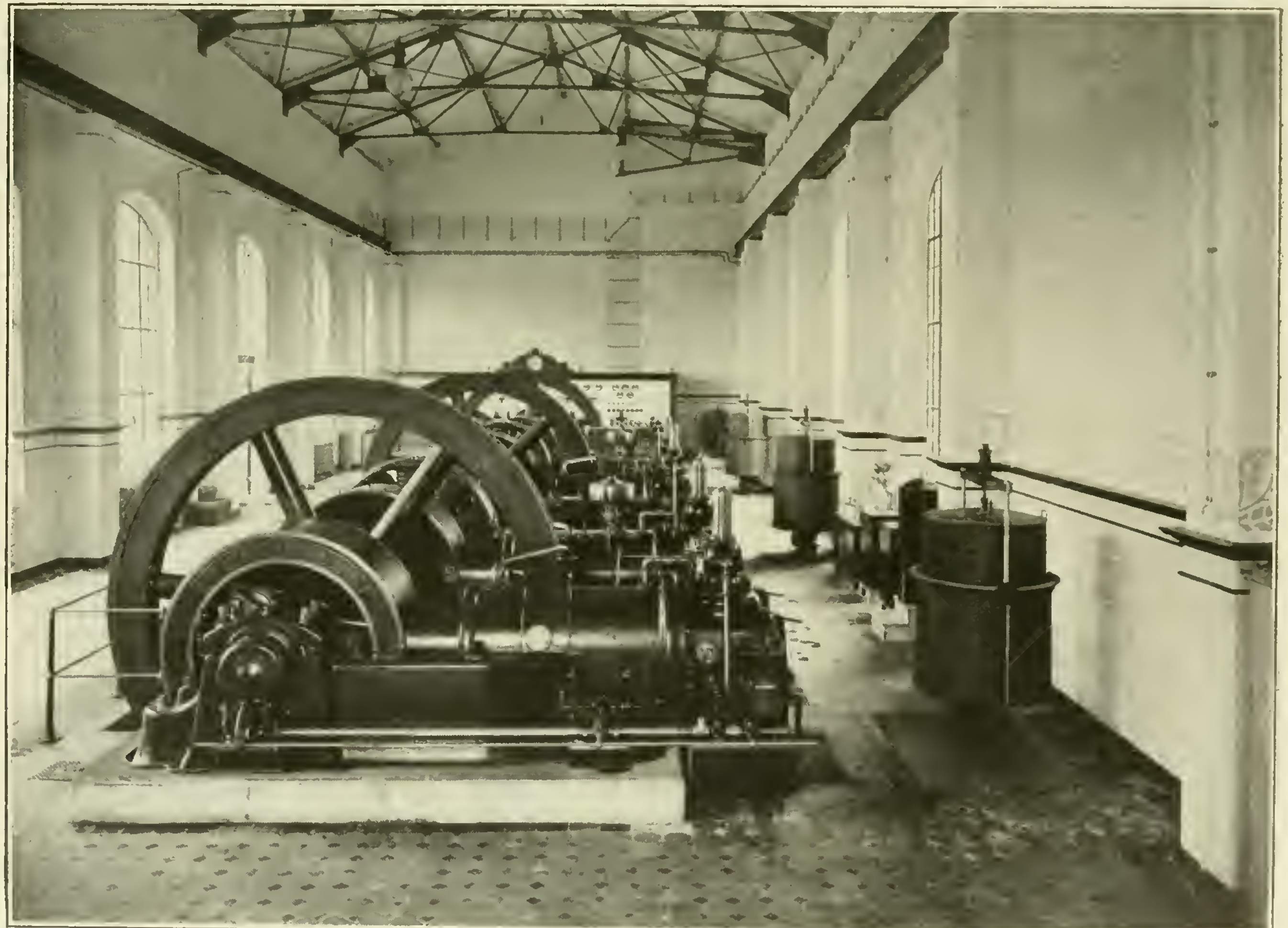


FIG. 7. ENGINE ROOM. (650 H. P.)
Direct-Connected Electric Generator Plant with Twinned, Single-Acting, Four-Cycle Engines.

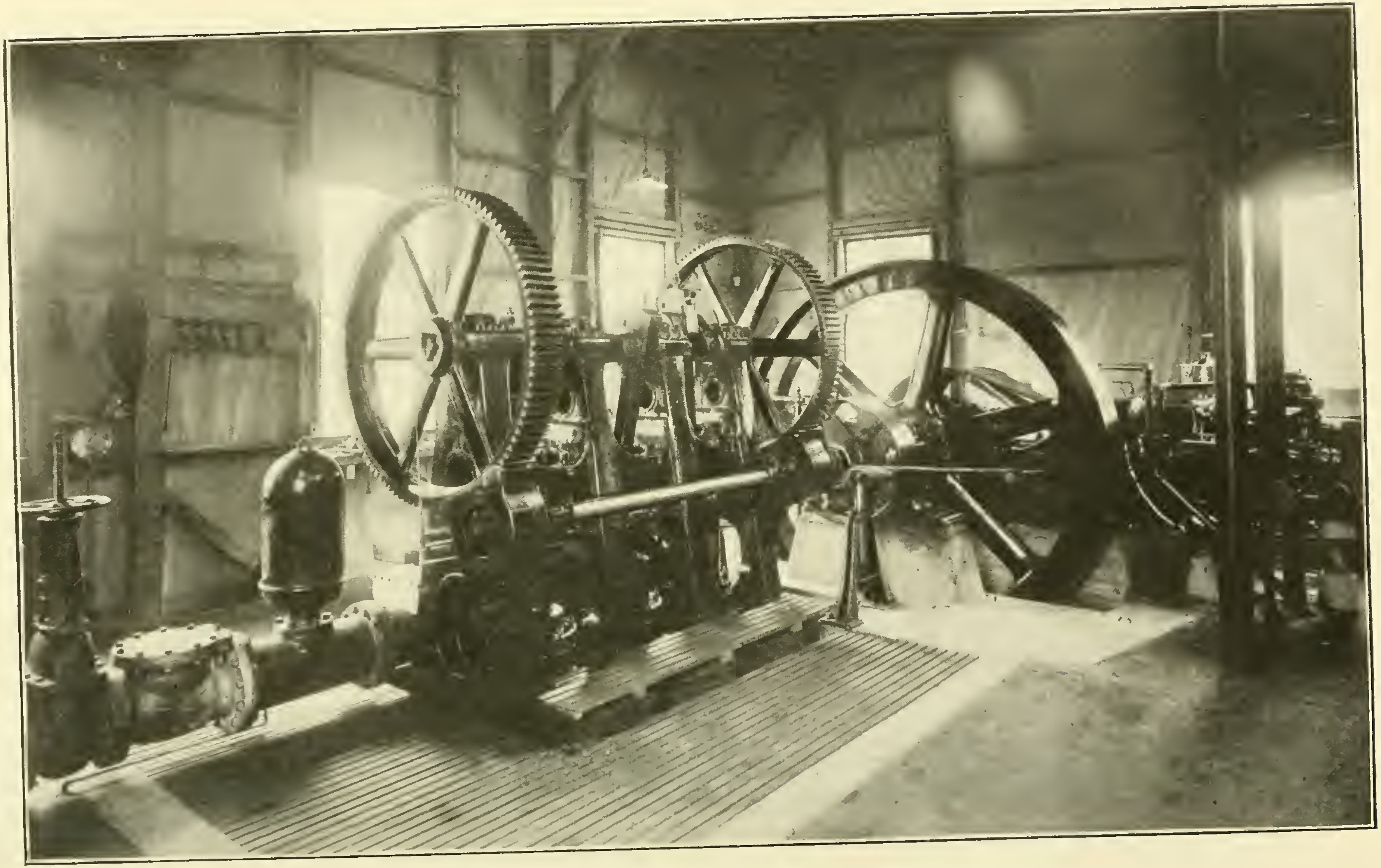


Fig. 8. Direct-Connected Plunger Pump Plant for Water-Works Service.

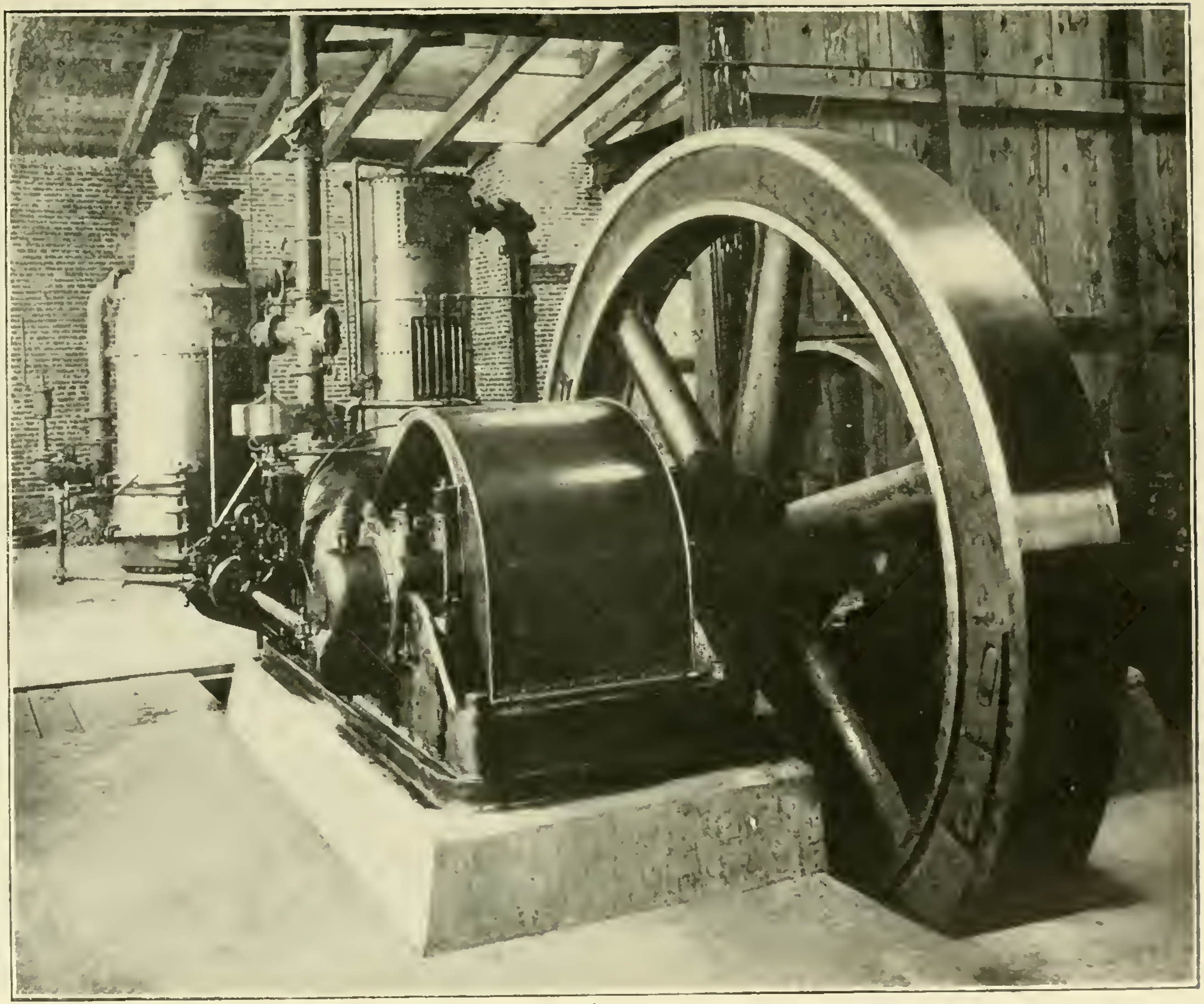


Fig. 9. Factory Drive Plant. Olds 65 H.-P. Engine and Producer, Pottsdown, Pa.

Many devices have been developed for this purpose; it may be said that those are best which have the simplest construction and fewest working parts.

The gases from the gas generator will be found to be hot, having a temperature of between 800 and 900 degrees fahr., and also dirty, as they will carry with them fine dust from the generator and will also contain certain portions of tar, the amount of tar depending on that contained in the coal originally.

A cooler is, therefore, provided by which the gases are reduced in temperature. It was found that enough heat was contained in these gases to generate the steam necessary to cool the fire of the producer. This cooler, therefore, is formed in the shape of a vaporizer. There are many different forms of vaporizer, but perhaps the most common is that of a tubular heater, the water being admitted to the vaporizer and simply overflowing through a vent, the amount being adjusted to the maximum demand of the producer and, when loads are light, the excess flowing away. The vaporizer is not under pressure as regards steam, the steam being sucked away from it by the suction of the engine which draws it underneath the grates.

The gas being still dirty is then passed through a scrubber, which amounts to nothing more than a tank filled with coke over which is spraying water from a rose nozzle in the top. The gases enter at the bottom of the scrubber, pass up through the coke and out at the top. In this passage they are cooled down to the temperature of the water and any dust which they carry is deposited in the coke. This coke being continually washed down, is kept free from the deposited dust, the dust being washed out through a water-sealed trap and carried away.

The gas is now clean and cool but wet and should, therefore, be passed through a cleaner or dryer. This cleaner usually consists of a tank with a removable top in which rest wooden grids having sawdust laid upon them; the sawdust takes up the moisture from the gas and it trickles down and out through the water seal to the sump. The last fine particles of dust are also deposited on the sawdust, a certain amount finding its way through the scrubber. The gas, after coming from the cleaner, is thus clean, cool and dry and is in suitable condition for use in the engine.

Figure 3 shows an assembled producer with the pipe connections. It will be seen that it consists of a little more than a high base-burner stove and three tanks. The whole system is under vacuum of about 1.5 in. of water, this vacuum being

caused by the suction of the engine; therefore no gas can leak out of the system. If any leak occurs in the mains it will be air leaking into the gas.

The producer can be charged with coal while running, the fire can be seen by opening the stoking door, grates can be shaken and ashes removed by opening the ash door, all without disturbing the operation of the producer, which is, therefore, continuous.

There are other types of producers which I will not take the time to discuss, one type being known as the " Pressure Producers " in which air is forced under the grates. There are many types of intermittent producers in which the fire is first blown hot with air and then cooled with steam, 70 B.t.u. gas being formed while blowing air and 360 B.t.u. gas while blowing steam. The pressure producer has the disadvantage that the fire cannot be seen or ashes removed while in operation; and the intermittent producers require close attention as the changes must be taken care of every one and a half or two minutes. The suction anthracite producer, therefore, for small plants has become very widely used. These producers have been built for plants up to 1 500 h.p. and operate successfully in this size. Such a size, however, is only possible where the cost of anthracite fuel or coke is less than that of bituminous coal — the suction producer not being as yet capable of burning bituminous coals or fuels containing tarry products, although experiments along this line show promise of success.

Figures 4, 5 and 6 show a 600 h.p. suction producer with vaporizer, scrubber and cleaner, also charging floor.

A blower is usually attached to a suction producer and, in ordinary sizes below 100 h.p., a hand-driven blower is sufficient for blowing the fire warm when starting up the apparatus. After the fire is hot and the gas begins to generate, the blowing is discontinued and the engine can be started, after which the suction of the engine is sufficient to keep the fire warm.

A suction producer can be used not only for power purposes, but for heating purposes, as it forms a combustible gas efficiently, the efficiency of the producer being 80 per cent., which is better than most boiler efficiencies. The gas so generated can be burned, with proper nozzles and air supply, in heating furnaces. Annealing furnaces are operated very satisfactorily with 130 B.t.u. gas, a bright cherry red temperature being maintained in the fire. Case hardening furnaces and malleable iron converters can be operated with this gas.

If producer gas were used for heating systems the efficiency

would be at least as great as that of a boiler outfit using coal direct, and, by judicious placing of the nozzles, local strains could be avoided in the boiler, as the heat can be applied wherever desired. No smoke would be formed owing to complete combustion, and in annealing and case-hardening furnaces temperatures can be gaged much more accurately with a gas than with a coal fire, the heat being more steady and reliable. This paper, however, is supposed to be confined to the application of producers for power, and I will not discuss the other uses further.

Practically the only means of using gas to generate power which has so far been developed has been a reciprocating engine. There are certain uses, such as the raising and lowering of railway gates, which have been successfully worked out by the use of a direct-acting piston and having no rotary parts or fly-wheel; but these are only special cases.

The rotary gas engine, as well as the gas turbine, has been receiving some considerable attention from engineers, but, as far as the rotary gas engine goes, there seems no reason to believe that it will be any more satisfactory than the rotary steam engine, which has never yet come up to commercial requirements.

It is too early as yet to make any broad statement regarding the gas turbine, as means may be found by which the excessive temperatures may be taken care of.

However, our present means of converting gas into power is the reciprocating gas engine. There are, of course, many devices and a large number of designs for such machines which we will discuss later. The reciprocating gas engine is confined within rather narrow limits as regards speed ranges; more than 50 per cent. variation of the speed of a gas engine does not seem to be possible; therefore, in the application of the reciprocating engine to power drives this fact is a primary consideration which is borne in mind.

Power systems may be divided into two classes: Those which can be put into motion without load, and those which must start into motion against the full resistance of the load.

It will be seen that the first class is more applicable to gas engines than the second, as it means that the drive can be a solid connection to the engine shaft and the engine still be started, the usual means for starting the engine being by compressed air and the engine not developing its full power until up to speed. With the second class of drive, the only means of connecting the engine to the drive is through a friction clutch or its equivalent. This latter class of mechanism has always been a

source of trouble, and is certainly not so reliable as the solid connection.

To the first class belong certain types of factory drives, electric generators, centrifugal pumps; while to the second class belong plunger pumps, air compressors, hoisting engines and certain other factory drives.

As a general rule, then, it will be seen that there is sometimes a choice between the two classes of machinery for connecting to the engine. It is usually better to use an apparatus from which the load can be removed and which can be direct connected to the gas engine, the load being applied later. There are cases, however, where this is impossible and, in such cases, it is necessary to use friction clutches; the only comfort in doing so is that while a friction clutch is bad, the great saving made by using a combustion engine over any other type of prime mover offsets the disadvantage.

For factory drive work, in case the machines in the factory can be thrown off from the line shaft, the gas engine can be direct connected to the line shaft without clutch, as the engine should have fly-wheel enough to get over the first cycle when starting the shaft in motion. Where the load cannot be disconnected or thrown off from the line shaft, it is necessary to use a friction clutch.

Electric generators and centrifugal pumps can be driven direct or by belt from the engine without clutches, and these two pieces of apparatus are coming to be used very widely for connection to a gas engine.

Plunger pumps, air compressors and hoists must, of necessity, be coupled with friction clutches to the engine, although even with these a proper by-pass arrangement can sometimes be made by which pump or compressor can be started without load.

Figure 7 shows a direct-connected electric generator plant with twinned, single-acting, four-cycle engines. Figure 8 shows a direct-connected plunger pump plant for water-works service. Figure 9 shows a factory drive plant.

I regret that I have been unable to obtain a photograph showing a compressor plant, but will say that with air-compressors the speeds now available in this type of machine will allow of direct connection between the compressor shaft and the gas engine shaft. The writer had the pleasure of seeing a compressor of 150 h.p. running at 600 rev. per min., against 1 200 lb. pressure, operating with the greatest smoothness. It will

thus be seen that compressors are available for direct connection to gas engines.

The compressors mentioned above are used by the United States government on many of their battleships.

As regards performance of plants, the best gas engine records show that a brake horse-power hour can be developed for 9 100 B.t.u. of heat value in the gas. This was a test on a 125 h.p. Koerting four-cycle engine with illuminating gas of about 600 B.t.u. per cu.ft. With the leaner gases, such as producer gas of about 135 B.t.u., one brake horse-power hour has been developed for 10 000 B.t.u., this with a 500 h.p. Oechelhæuser engine. A 60 h.p. Anhalt engine got off with 10 250 B.t.u. per brake horse-power hour. A Premier engine with 135 B.t.u. gas used 9 100 B.t.u. per brake horse-power hour.

It will thus be seen that with the leaner gases the efficiency is slightly less than with the richer gases and that the size of the engine does not affect the efficiency except in a slight degree. This is a point which affects very radically the design of gas power stations, making it advisable, in most cases, to use smaller units and more of them.

The efficiency of suction producers will average about 80 per cent., and by figuring back from the heat value required per brake horse-power hour at 9 100 B.t.u. in the gas will mean 11 370 B.t.u. required in the coal per brake horse-power hour, which seems to be about the best performance with producer engines. An average pound of coal will have 12 500 B.t.u.; the fuel consumption, therefore, will be equivalent to 0.91 lb. per brake horse-power hour with the Premier engine. The test of this engine was made some years ago and since that time the art has been developed, so that practically any producer engine will develop this efficiency at the present time. A general trade saying is that "a brake horse-power hour can be developed for a pound of coal"; this is at full load.

What one wishes to know is: How much coal is needed to operate a plant under actual conditions? Therefore the best figures for comparison are performances extending over a year's time, all charges to be included. These figures are naturally rather difficult to obtain. These values are expressed in different terms for the different classes of service, but they will be intelligible to those who are interested and can be figured back into pounds of coal per horse-power hour.

These figures include all fuel charges for a year.

Water Works. Triplex-Geared Pumps.

Ordinary water works heads, 100 lb. of pea anthracite coal will develop 125 000 000 ft. lb. of work in water delivered.

(Running 10 hr.; banked 14.)

Water Works. Centrifugal Pumps.

One hundred pounds of pea anthracite coal will deliver 100 000 000 ft. lb. of work in water delivered.

(Running 10 hr.; banked 14.)

Electric Lighting Stations.

One kw. can be generated for 2 lb. of pea anthracite coal.

(Running 24 hr. but with varying load.)

Ordinary Factory Drives.

One brake horse-power hour can be delivered for 1.25 lb. of pea anthracite coal.

(Running 10 hr.; banked 14.)

The above figures can be maintained during a year's run under ordinary conditions. Plants are already in existence doing this service; in fact, in certain cases better records are made, but I consider these to be a very fair average for suction producer performance with the different classes of service, and these performances can be made with plants of not over 50 h.p.

The best record of the Milwaukee 18 000 000 gal. triple expansion engine, running 23.72 hr. per day at full speed, is 122 000 000 ft. lb. per 100 lb. coal. The indicated horse-power of this engine was 540. As compared to this, a 50 h.p. producer gas engine, running 24 hr. per day, made a duty of 156 000 000 ft. lb. This triple expansion steam pump, when operated 63 per cent. of the time, developed a duty of 99 043 000 ft. lb. per 100 lb. of coal. The 50 h.p. producer gas engine, when operated 41.5 per cent. of the time, made a duty of 125 000 000 ft. lb. In other words, a producer plant having one tenth of the capacity of the triple expansion steam pumping plant made a duty of approximately 25 per cent. in excess of the latter, both on test and under running conditions. This is comparing the very highest type of steam pumping apparatus with an ordinary producer. It is true that later pumps of the triple expansion type have made duties of as high as 181 000 000 ft. lb., but this is practically the limit for any type of steam apparatus and the pumps are 36 000 000 gal. capacity.

If a producer pumping plant, however, is compared to a steam plant of its own size, it will be found that the yearly duties will certainly not exceed 50 000 000 ft. lb. with a very high grade of small pump, ordinary direct acting pumps going as low as 25 000 000 ft. lb.

The same general proposition holds true for all classes of work, the very smallest producer plants will make practically the same fuel economies as the very largest and highest grades of steam apparatus and, when compared to steam plants of equal size, will consume about one fourth to one sixth of the fuel. A 50 h.p. electric plant, with producers, will make a kilowatt per hour for 2 lb. of coal. A modern steam plant of the largest size requires 4.25 lb. of coal per kw. hr.; a 50 h.p. steam plant will require as high as 15 lb., 10 lb. being the lowest limit under the very best conditions, 15 lb. being required when loads are variable and the plant only operating 10 hr. per day.

It is to be borne in mind that a steam plant operates with bituminous coal and that the present suction producer plant requires anthracite; therefore, depending on the locality, the cost of these coals will vary from points where anthracite is cheaper than bituminous and where it costs three times as much. As a rule, however, pea anthracite coal will cost twice as much as bituminous coal can be procured for. As a general rule, then, it can be said that a producer plant will save half of the cost of fuel as compared with a steam plant using bituminous coal. That is, it uses one fourth of the coal which costs twice as much per pound.

The fixed charges with the two types of plants should be about equal; that is, the percentages should be about the same. Producer plants are usually more expensive than equivalent steam plants; therefore, the fixed charge against a producer plant is greater; this, however, is usually offset by the saving in labor. Up to 300 h.p. one man can operate a producer plant with ease, taking care of both producers and engines; with a steam plant this would require two men. The saving in labor, therefore, offsets any increase in the fixed charges, so there should be a clean saving in the difference in fuel cost.

It is necessary at times to make provision for heating buildings in connection with power plants. In this case a credit occurs to both plants. With a steam plant all of the exhaust steam is used for heating and usually some extra coal during the six months of the year, while with a producer plant the exhaust gases from the engine can be used for the same purpose but will

have to be supplied with fresh gas from the producers to make heat enough. In either case the efficiency of the whole power and heating system amounts to practically the same thing for the six months, as with either system about 60 per cent. of the heat value of the coal can be turned into power and useful heat in the building. This is supposing the boilers to be in good working condition. During the remaining six months of the year, however, a steam plant has to waste its exhaust heat into the air by running non-condensing, and a producer plant, during these months, will make the saving mentioned above of about one half the fuel cost; as this only extends over six months, however, the actual saving, where it is necessary to heat buildings, will be about 25 per cent, or one fourth of the fuel cost.

It will be understood that these figures are rather rough approximations, as each particular case is individual and should be carefully calculated by itself. However, it can be said roughly that where it is not necessary to heat buildings, the only requirement being the generation of power, a producer plant will save half the cost of fuel as compared with a steam plant; and, where it is necessary to heat buildings, it will save one quarter of the cost of fuel as compared with an equivalent steam plant.

A gasoline plant usually requires three times the fuel expense of a producer plant, but fixed charges are enough lower to sometimes make such an outfit available. Water power is, of course, the cheapest but can only be obtained in a few localities, and even then depends upon the flow of water, which is variable and uncertain. Crude oil engines of the Diesel type are doing good work but usually require three to four times the cost of producer gas fuel and the fixed charges are as heavy.

Concerning the best types of producer gas engines, the simplest machine compatible with efficiency and durability is the best; for this reason, on many grades of work, a single cylinder is better than a multiple cylinder machine. For driving pumps, air compressors, most kinds of factory drive work and ordinary store lighting, single cylinder engines will give a steadiness of running which is perfectly admissible. For the finer kinds of electric lighting it is necessary to have at least two cylinders. Especially is this the case with alternating current generators which have to be run in parallel with other machines.

As a matter of choice between vertical and horizontal engines, unless space is so limited as to require a vertical engine, the horizontal is preferable. With this type of engine all of the parts are accessible, pistons can be removed without taking off

the cylinder, the valve gear is within easy reach of the floor where it will receive proper attention. Vertical valves can be used, giving a very small compact combustion space, and the lubrication of the cylinder is absolutely controllable.

A point which has been raised against this type of engine is the wear of the piston on the cylinder. It may be said, in this connection, that the only difference between a vertical and a horizontal cylinder, as regards this point, is that with a horizontal machine the weight of the reciprocating parts comes against the bottom of the cylinder, this not being the case with a vertical engine. It will readily be seen that in an engine in which the reciprocating parts weigh 300 lb., the pressure on the side of the cylinder, due to the pressure on the head of the piston, will amount to seven times this figure. In other words, the weight of the parts is only one seventh of the total pressure on the side of the cylinder and this increase can readily be taken care of by a small increase in the surface of the piston. Moreover, with a horizontal cylinder the cylinder itself can be supported direct from the foundation, which is not the case with a vertical engine where the heavy side thrust of the connecting rod is distorting the cylinder and tending to force it off to one side at each explosion.

The lubrication of a horizontal cylinder is easy, because if a drop of oil is placed on the top of the piston it will run down both sides of the piston to the bottom, covering the entire circumference with lubricant, which is then wiped end-wise the full length of the cylinder by the piston in its travel. In this way every point of the cylinder is lubricated. In a vertical engine no means has yet been devised by which a single drop of oil can be spread over the whole surface. Gas is not like saturated steam in which there is a fine mist of water in turbulent movement and in which a drop of oil upon entering will immediately be torn apart and distributed over the surface of the myriad small particles of water in the steam by capillary action, later being deposited evenly on the inner walls of the cylinder when the steam enters it through the cylinder port.

Gas has no entrained water or vapor which serves to carry and break up this oil; therefore the oil goes in as a drop into the cylinder, being thrown against the opposite wall of the cylinder, where it remains lubricating this side only. In a vertical engine, therefore, it is necessary to use splash lubrication for the cylinder; this means that the cylinder is always over-lubricated, causing ignition troubles by a deposit of oil and

accumulating on the piston head and inner surface of the combustion space, thereby causing pre-ignitions.

The difficulty of spreading oil with any gas which does not contain water was well demonstrated in the days when superheated steam was just beginning to be used for steam engines. Superheated steam, of course, contained no vapor or water to spread the oil and it was found necessary to immediately abandon the old methods of oiling and carry the oil with pipes to every working surface direct to the point where it was to be used, and even at that it was a difficult matter to keep cylinders from cutting, even though the amount of oil was increased many times. It is my opinion that the horizontal engine is better, under any conditions, for producer gas service, the question as to whether one or two cylinders shall be used being answered by the statement that one cylinder should be used wherever possible without going above 150 h.p. in one cylinder, double cylinders being used only when sizes exceed this amount or when very close regulation is desired, as in parallel alternating current work.

Where two cylinders are used it is better to place a fly wheel between the two cylinders, and if it is not possible to take the work from fly wheel or pulley between the two cylinders, take it off from a tail shaft outside of the unit, as shown in Fig. 7, where it will be seen that the generator is on the far side of the second cylinder, the fly wheel being between the two. By this arrangement the explosion strain is taken directly from the crank of its own engine to the fly wheel, whereas, if the fly wheel were placed outside of the unit the explosion strain of the first engine would have to go through the crank of the second to reach the fly wheel.

For pumping work a single cylinder is satisfactory; there the speed variations do not make any particular difference. Most factory work can be done with a single cylinder, although some of the fine spinning mills require regulation almost equal to alternating parallel work.

The ignition system for producer gas work should be of the make-and-break type and, where absolutely continuous service is desirable, a double ignition system should be used from two independent sources of current.

Compressions for producer engines should be in the neighborhood of 175 lb. per sq. in. as against about 80 lb. with an ordinary illuminating gas engine. This means that the engine must be especially designed and will have a weight of almost

twice as much per h.p. as the average gas engine upon the American market to-day.

All anchorages for fly wheels and parts taking sudden strains should be by double key or some method of increasing the strength of the tie. In fact, the design all the way through on these machines should be with the idea that one is building a gun instead of an engine; if this is carried out trouble with breakages and weakness of parts will not occur.

The problem of plant arrangement is different with a gas engine and with a steam plant. In the first place, owing to the fact that small engines are practically as efficient as large ones, it is best to use small units and more of them, as stated before. The usual plant which has any serious service upon it has at least one relay engine, and if the whole plant can be cut up into several small units the relay engine is a much smaller percentage of the whole plant cost than as though the whole power were in one unit and the relay engine had to be of equal size.

Moreover, the usual power plant to-day has a variable load, the changes going over a wide range, and by having several small units the load can be followed up or down by cutting in or out more machines, thus keeping the remaining machines which are in service operating at nearly full load, which is their economical point.

Of course the best layout for a plant is to have either electric generators, pumps or compressors direct connected to the main engine shaft. This is the most compact station layout that can be made, and the only reason that it is not used universally is because of the considerably greater cost.

A satisfactory layout where a number of machines are to be used is to belt from each engine fly wheel to a jack shaft; from the jack shaft anything can be driven. In this connection it should be said that only the highest grade of jack shaft should be used. The writer has found that the quill type of shaft, in which the strain of the driving belt is carried upon a pulley mounted on a hollow quill which has its own bearings and does not run in contact with the main jack shaft at all, is the most satisfactory. The quill has part of the friction clutch mounted on its end outside of one of its bearings and the other part is mounted on the jack shaft and, therefore, when any engine is standing the jack shaft can rotate without any strain from the driving belt and without being in contact with any standing part. It has never anything to bear except a torsional strain which is perfectly central.

Means should be provided for easy handling of coal and ashes from the producer room although, owing to the small quantity of coal used, this is not a very serious matter.

It may be considered as demonstrated that suction producer gas plants are the most economical of all types for power generation, using the term broadly, but assuming that they are equipped with machinery especially designed for the work. If machines are installed which embody the same sound engineering principles that have been used so successfully in other classes of engineering design, the same practical results in low repair charges, reduced attendance and certainty of operation will follow.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by March 15, 1907, for publication in a subsequent number of the Journal.]

THE MAINTENANCE OF SEWAGE FILTERS IN WINTER.

By George E. Bolling, Member of the Sanitary Section of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, December 5, 1906.]

The sewage filtration plant at Brockton was first put into commission in November, 1894, and consequently the disposal of the sewage in winter was the first problem encountered there. In preparation for that winter some of the beds were left level and some were furrowed, and in comparing the efficaciousness of the beds left flat with those that were plowed into ridges I can do no better than to quote from the Annual Report for 1894 of Mr. F. Herbert Snow, then city engineer of Brockton, who wrote under the heading, "Effect of Frost on Level Beds":

"Considerable ice began to form early in December, 1894, around the edges of the level beds, and gradually to approach the carriers. The temperature of the sewage, at this time, about 44 degrees fahr., was readily chilled by the snow to a point where it had little power to melt the ice. Observations, made while putting sewage into snow, showed the temperature to be: in the pipe, 45 degrees fahr.; 20 ft. away from the carrier, 43 degrees; 50 ft., 42 degrees; 75 ft., 37 degrees; and beyond this the sewage did not penetrate the snow at all. Within this area the liquid retained in the upper inches of the filter by the accumulated organic matter froze solid. At a greater depth than 2 in., less liquid being retained by the sand grains, though frozen, the mass remained porous. If there had been warmth enough in the applied sewage to thaw the upper layers it would readily have passed through the lower porous, though frozen, sands. But it is easy to understand how the sewage flowing in a thin sheet became chilled by the ice and snow to a point where it could not thaw its way through the upper frozen layer, thus rendering the level beds entirely useless until warmer weather."

After the experience of this first winter, the system was adopted each fall of plowing into ridges all the beds that were intended to be used during the following winter, leaving level only those that were not required in the operation of the plant. Within a few years, however, the increasing volume of sewage demanded the use of these few reserve beds, and so, after about 4 years of operation, the entire complement of 23 beds was furrowed each fall in preparation for the freezing weather to follow.

As first practiced in preparing to furrow a bed, it was first plowed and harrowed, and then furrowed, but it was found on trying the experiment that unless a bed had had considerable heavy teaming done over its surface and the soil was packed down hard, the preliminary plowing and harrowing could be dispensed with, and the flat bed furrowed directly into ridges, thus saving the extra item of expense.

In making the furrows we use a common Ames No. 2 double-moldboard plow, with an extra iron form attached to the moldboard, which enables a deeper cut to be made, and the flaring edges round over the shoulders of the ridges, leaving less loose material to fall or be washed down into the furrows.

At present, the beds are prepared for winter use with the top of the ridges about 3 ft. apart, and the furrows about 12 in. in depth. It is found after a bed is newly furrowed that, for the first four or five doses applied, material from the sides of the ridges will be washed down into the bottom of the furrows, but after the fourth or fifth dose very little is washed down. This washing of the material down into the trenches is of no particular moment except in case of the sludge beds where alternate layers of sludge and sand are deposited, necessitating the removal of considerable of the filtering material when the beds are cleaned in the spring. It is customary with us to dose a newly-furrowed bed that is to receive sludge during the winter with one or two preliminary doses of the lighter sewage, as it is in the first one or two doses that the most of the loose material of the sides of the ridges is washed down into the trench.

The one great object to be accomplished by furrowing a bed for winter use is, of course, to keep the ice which in this latitude is certain to form in an ordinary winter from attaching itself to the whole surface of the filter.

In our experience, frost cannot be kept out of the trenches; in fact in a winter of ordinary severity the frost penetrates down into the bed 8 or 10 in. below the bottom of the trenches. This frost line in a way is comparable with a water table, in that it conforms to the configuration of the surface of the ground, and while almost the entire ridge may be frozen solid and the frost have penetrated down into the bed nearly a foot below the bottom of the trenches, the unfrozen sand under the ridges is nearer the sewage when it is applied than is that directly under the furrow. Therefore, the sewage when flowing in the trenches of a furrowed bed exposes less surface to the cold and has its warmth conserved while thawing through the frost to the more

porous sand. It is our experience that as the strength of our sewage has increased and the amount of sediment deposited in the trenches has become consequently greater, presenting an almost impervious layer to the applied sewage, much of the absorption into the body of the filter takes place diagonally downward through the sides of the ridges.

On the application of a dose of sewage to a furrowed bed in the winter absorption does not take place until the warmth of the sewage has thawed out a way for itself along the path of the least resistance. While this is occurring and there is no settling of the sewage a sheet of ice forms on the top, and when subsidence is finally effected this ice is left supported by the top of the ridges, affording an additional help in conserving the heat of the additional doses applied to the bed.

The foregoing has been our experience with furrowed beds in winter. We never have had a bed that was left level for winter use completely freeze up, so as to be of no use, except in one instance. This was in the case of a sludge bed, from which the sludge was removed so late in the season that when the bed was ready to be furrowed a sudden cold snap made it impossible to work the frozen ground. On attempting the use of this flat bed during the ensuing winter, the first dose froze to the surface of the ground and successive doses merely flowed out on top of the ice and added to its thickness. This, however, was a bed from which, during the construction of the plant, the subsoil had not been removed. The belief that the fact of its being a subsoil bed was responsible for its freezing is strengthened by our experience with Bed 23 in the winter of 1903–1904. This is a bed from which the subsoil had been completely removed at time of construction, and which for the winter of 1903–1904 was left level.

In November, four doses, averaging 112 000 gal. each, were applied, the average time of absorption being 60 min. In December but one dose of 112 000 gal. was applied; this required 3 hr. for absorption. The mean temperature for this month was 28 degrees above, and the minimum 5 degrees below zero. In January there were three doses applied of 250 000 gal. each, and the time of absorption averaged 20 hr. The mean temperature for this month was 21 degrees, while the extremely low minimum of 33 degrees below zero was recorded at the filter beds on the night of January 4.

In February, but one small dose of 50 000 gal. was applied, this being absorbed over night. The mean temperature of the

month was 14 degrees above, and the lowest, 3 degrees below zero.

In March fifteen doses of 180 000 gal. each were applied, being absorbed in the average time of 8 hr. Mean temperature of the month was 35 degrees and the lowest 6 degrees above zero. In the first week of April and once again in the second week, a slight clogging of the surface of the bed was remedied by going over with a one-horse spring-weeder, and the bed was continued in use on alternate days until it was cleaned and plowed in the first week of June.

The bed continued to yield a good (for winter) effluent during this period; the analysis of a sample collected March 30, 1904, being as follows, in parts per 100 000:

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	O. Cons.
1.3040	0.0700	6.32	0.450	0.0170	0.75

Compared with the applied sewage, the purification effected is shown by the removal of 75 per cent. of the free ammonia, 97 per cent. of the albuminoid ammonia and 97 per cent. of the oxygen consumed; and this on a level bed during the most severe winter on record for years.

If asked what was the nature of the material composing this particular bed and the effective size and coefficient of uniformity, I should be stumped for an answer, as about any kind of material one could desire is to be found in that bed. In one test pit, 5 ft. in depth, I have observed and collected samples from nine different strata varying from a coarse porous gravel to a hard clay. In February, 1904, frost was found to have penetrated to a depth of 20 in. into the filter. This bed was underdrained at a depth of 6 ft.

This same winter of 1903–1904 was the most disturbing one to our peace of mind since the plant has been in operation. The long-continued low temperatures in January caused the formation of ice in the bottom of the trenches in nearly all of the beds. It was not over the entire area, but started first around the sides by freezing the sediment remaining in the furrows, and then the whole section of the furrow itself filled with ice as successive doses were applied, until in some cases a third of the bed was frozen solid and unavailable for filtration purposes, the rest of the bed simply being put to it to do the work of the whole area.* The worst bed was Bed 1, a sludge bed, in which the ice increased

* In an ordinarily severe winter the ice on the beds would vary from .5 in. to 6 in. in thickness.

to a thickness of 40 in., and only about one half of the bed was available for absorption of the sewage. One of the laborers was so impressed by the glacier-like expanse of ice in sight on this bed that he ventured the opinion that it would be a nice, cool place to come and sit in the hot days of the following summer, as he couldn't see how all the ice he then beheld could possibly melt in the short space of a few months. The ice on this bed hardly lingered long enough to give us a little trouble when it was cleaned in the second and third weeks of April.

For about 8 years in the operation of the plant the application of sewage to furrowed beds during the winter months was followed by the proper subsidence of the sewage, within a period of from 4 to 48 hr., leaving a dry bed ready for the next dose. After this time the gradually increasing amount of organic matter in the upper 6 to 8 in. of the beds had reached a point where in both the sides of the ridges and in the bottoms of the trenches a clogging occurred that would not permit the absorption of the sewage until such a depth was put on to the bed as provided a sufficient head to force the sewage through the clogging material. When sewage was applied to a bed it would gradually increase in depth from 0.5 to 1 ft. above the top of the ridges, at which point a head sufficient to force absorption was attained.

It may be thought that considerable deterioration in the quality of the effluent would be apparent about this time, but such was not the case, as the winter effluent from any of the plants in this region treating sewage at all approximating the strength of Brockton's sewage is none too good. A view of the plant at the time of the spring thaw would lead the uninitiated to believe that all the water coming to us during the whole winter past was piled up on the beds, until a little calculation would show that if such were the case the beds instead of being covered with 12 to 18 in. of sewage would be inundated by from 25 to 30 ft. of it. It was necessary during a few successive spring cleanings in order to get at the surface of the beds to facilitate the absorption of this supernatant sewage by going over the clogging material of the surface with rakes. This was necessary in order that it might be absorbed before the increasing warmth of the spring produced a nuisance. In the winter, of course, no odor from the beds was noticeable. This raking over in the spring to hasten absorption would cost from $3 to $10 per bed, and occasionally a particularly obstinate bed would cost $20. This cost has been largely eliminated the last few years by trying

the scheme of cleaning one or two of the lower elevation beds before the others, levelling them flat and then, by means of pipes laid through the low embankments, drawing off the supernatant sewage of the other beds on to those freshly prepared, where it was readily absorbed.

An especially good feature of the seven additional filter beds added to our plant in 1905 is that they average 8 ft. lower in elevation than our old beds, so that in the spring, when the supernatant sewage on the old beds is at its greatest height, it is drawn down on to three of the beds of the new plant by means of a specially constructed masonry chamber.

To be ready for this purpose in the spring these three new beds are left level during the winter, and it was our intention during last winter, which was the first time of its trial, not to use them at all for the disposal of sewage during the winter months. But the continued mild weather induced us to keep up their use during the winter months, so that it is possible to give a few comparisons on the use of three furrowed and four level beds during their first winter's service, bearing in mind, however, the fact of its being a very open winter.

Beds 24, 25, 28 and 30 were left level and Beds 26, 27 and 29 were furrowed; all were dosed on an average every third day, and once in a while every second day during the months of December, January and February, each bed having 35 doses during the three months, the size of the dose being the same in all cases, about 135 000 gal. per acre. Each bed dried after each dose it received, the flat beds averaging 7 hr. for absorption, and the furrowed beds 8 hr.

These 3 months are selected as they were the coldest months of the season, but the beds were continued in use throughout March and April, until they were cleaned early in May. The amount scraped from the level beds averaged 246 loads per acre, while from the furrowed beds 375 loads per acre were removed.

Observations extending back during a period of 10 years show the average coldest temperature of the sewage during the year to be 43.8 degrees, occurring in the month of March. The average coldest temperature of the effluent in the same period of time was 40.4 degrees, also occurring in March.

In the summer of 1905, as the beds continued to become slower in absorbing sewage, an attempt was made to remedy this by removing from 19 beds 6 in. of the surface material. In all about 16 400 cu.yd. were removed at a total cost of $4 314.36.

This material removed varied in amount of organic matter, as shown by the "loss on ignition" from 0.7 to 4 per cent. by weight. It varied in "organic nitrogen" from 90 to 280 parts per 100 000 parts.

This removal quickened the absorption of the beds thus treated during the remainder of that summer, and also during this summer, but in the winter of 1905–1906, the same tendency of the sewage to pile upon the beds was observed. As our sewage has steadily increased in strength, and, consequently, in amount of sediment deposited in the furrows per dose of sewage, it is believed that the slower absorption of last winter is in part due to this factor. Prior to 1896 we have no data regarding the strength of the sewage treated; the plant was performing in 1905 just twelve times the amount of work imposed upon it 9 years previously, in 1896.

For purposes of comparison of the increasing amount of work accomplished by the plant in Brockton we obtain what we term an albuminoid factor by multiplying the yearly average of the albuminoid ammonia of the sewage for the respective years by the number of hundred million gallons of sewage treated during those years. This factor being obtained, its comparison with that of any other year shows at a glance the ratio of one to the other in work imposed upon the disposal plant.

This accumulation of the sewage upon the beds in winter in Brockton has not worked to any permanent disadvantage. The analysis of the effluent from these beds differs but little from what it was when the beds used to become completely dry between doses. To show that no permanent injury is done, the following typical analyses are given:

On April 20, 1906, when the effluent of Bed 12 was at its very worst, it presented in parts per 100 000:

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	O. Cons.	Bacteria per cu.cm.
3.1580	0.2600	7.95	0.000	0.0000	3.96	4 400 000

representing a purification as indicated by the amounts of free ammonia, albuminoid ammonia and oxygen consumed removed of 51 per cent., 91 per cent. and 69 per cent. respectively, and a bacterial purification of 66 per cent., the bacteria per cu.cm. in the sewage at that time numbering 11 000 000. On September 28 the same bed which had received but the customary attention in going over the surface and in scheme of dosing during the summer, gave an effluent which analyzed as follows:

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	O. Cons.	Bacteria per cu.cm.
0.0120	0.0150	16.90	4.00	0.0028	0.37	216

representing a purification as shown by the amounts of free ammonia, albuminoid ammonia and oxygen consumed removed of 99.8 per cent., 99.5 per cent. and 97 per cent. respectively, and a bacterial purification of 99.99 + per cent.

Many of the winter effluents, while appearing only slightly turbid at time of collection, after standing in the laboratory a short time begin to deposit a copious precipitate of iron which renders them very unsightly. This iron is derived from the soil of the filter beds and its solution in the effluent is facilitated by the amount of organic matter the winter effluents contain. Effluents carrying as much iron as 12 parts per 100 000 parts are not uncommon in the winter. The quality of the effluent improving as the summer advances, the iron gradually grows less in amount and finally ceases to be apparent.

It may be asked why, if this standing of sewage to a depth of, in some cases, 18 in. upon the beds is to be a regular occurrence each winter, is there any advantage in furrowing the beds at all. We believe that, if it were not done and continued cold weather should ensue before the sewage had reached its winter height, there would be a possibility of ice forming and attaching itself to the entire surface of the bed which would then, of course, throw the bed out of use for the rest of the winter.

As regards the relative cost of having the filters furrowed and leaving them level, there is not much to choose between the two.

The average cost of furrowing a bed is $3.30, and of shovelling the outlets from the carrier through the ridges so as to permit the distribution of the sewage over the bed is $1.91, a total of $5.21.

If the bed were left level for winter use we should consider it advisable to first plow and harrow it on account of the amount of teaming done over it during the summer; this would cost $4.17 for plowing and $1.02 for harrowing, a total of $5.19.

The item where expense might be saved is the greater ease in cleaning a flat bed. The average number of loads of sediment and dirty sand removed from a furrowed bed in the spring is from 200 to 400. On a flat bed this sediment could be gathered up without taking anything like as much of the filter material with it.

But here the question presents itself: Is not the furrowed

bed all the better off on account of having so much of the material with a tendency to clog removed from it?

DISCUSSION.

Mr. E. R. B. Allardice. — The Clinton sewage disposal plant was built and is maintained by the Metropolitan Water and Sewage Board. It comprises eight settling tanks and about 25 acres of filtering area, divided into beds of about 1 acre each. In the fall of the year, just previous to the time when freezing takes place, 5 of these 25 beds are furrowed. The sewage is delivered to these beds from an inlet which is placed at the middle of one side, and to carry the sewage directly across the bed three main channels are dug, which divide the bed into four equal parts. Then at right angles to these three main channels there are furrows similar to those described by Mr. Bolling, the furrows being 3.5 ft. apart and 15 in. deep. Previous to this work in the fall the bed is given a complete cleaning by raking up any scum or sediment which has formed on the surface during the summer. The sewage is applied to the furrowed beds at such times as the temperature at 7 o'clock in the morning is below 15 degrees fahr. When the temperature is higher the flat beds operate satisfactorily.

The furrowed beds are given doses which range from 500 000 gal. per acre upwards. The dose is sufficient to flood the bed to a depth of more than a foot above the ridges, and, before it has seeped away, a coating of ice some 2 in. in thickness has formed, so that when the sewage has entirely disappeared this rests on the tops of the furrows, thus protecting the bottom, which we find has never become frozen, always being soft and ready to carry away the sewage at the time of the next application. When the temperature is higher than 15 degrees fahr. we apply the sewage to flat beds in doses of 250 000 gal. per acre. This we find can be done at all times, unless there is deep snow on the bed. At these times we plow furrows in the snow, about 10 ft. apart, thus allowing the sewage to reach the far points as quickly as possible. But, unfortunately, this method of applying sewage has not been entirely satisfactory, the sewage becoming so chilled that a heavy coating of ice forms on the beds, and unless we have a few days of moderate weather the bed will be forced out of commission.

In the spring of the year, when the freezing weather has passed by, we find that there is sediment in the bottom of the furrows from 4 to 6 in. deep, and this has to be cleaned out and

carted off. We usually get from 275 to 300 loads from each bed. The quantity of solid matter has been greatly reduced by passing the sewage through settling tanks, which were built in the fall of 1904. The sewage is allowed to pass through one tank for two weeks at a time, and since they have been put in operation, which was only last year, we have not been compelled to clean the bottom of the furrows in the spring, the settling tanks taking care of almost all of the sludge which was in the sewage.

Mr. E. C. Frost. — Many reports have been made public explaining the methods employed in preparing the filter beds at Framingham, therefore it would avail nothing to describe them in detail here. Suffice it to say that the loam was removed, the beds graded, the cuts making the fill in many places, and in no instance was a filter wholly made of foreign material.

From the foregoing we can understand why it is that no two beds at Framingham are of the same character and they, therefore, cannot be treated the same, some being of much looser material than others and differently drained; therefore, we can have no fixed rule for flooding our beds unless it be " moderation " and " eternal vigilance."

We prepare the filters each spring by raking and removing sludge, plowing, and planting Indian corn in hills 3 ft. apart each way. A hill about 5 in. high is made around the stocks, which are cut each fall about 5 in. higher than the surface of the hill.

In flooding beds in winter I consider it one of the vital points to cover them quickly and to a greater depth than in summer. My reason for so doing is that, provided freezing weather prevails, the ice forms well up on the hills and there rests until melted away by warm rains which, of course, puts your filter in good condition again. Should the weather continue cold, be sure to flood the bed as quickly as possible, thereby melting a larger amount of ice than would be melted by running slowly. In this way the bed can be kept open a much longer time. The above method is carried out if we have a fall of snow when no ice protects the surface of the filter and for the same reasons.

A great mistake can be made if one should try to keep open too much filtering surface with a given amount of sewage during a continued " cold snap." After having learned the amount of sewage each bed is capable of handling satisfactorily it is then easy to determine how many beds are required to filter your supply, but a mistake can also be made by not starting with

enough. I always prefer to start with more than enough and keep as many of them in good working order as possible, and if I get a few warm days I always open up another filter or two, perhaps resting some that have had all they can do for a long time. Ordinarily there are sufficient warm spells or "thaws" during each winter of sufficient duration to enable me to open up others, so that practically all of our filters get their share.

Mr. L. M. Hastings. — What is done with the sludge taken out of the furrows at Brockton? Is there any difficulty in disposing of this large amount of sludge?

Mr. Bolling. — No, we have no difficulty. Last year we removed about 4 000 tons. Previously to that year we had sold the whole output to one farmer, who sold it in smaller quantities to others. We sold it to him for the sum of $150. Selling it obviated the necessity of cremating it, and he was responsible for taking it away as soon as we removed it from the beds. He had no trouble in getting the people to take it. This year we stopped charging him for it, but he promised to take it away just the same. He sells it for 25 cents a load, and there is about a ton in a load.

Mr. Hastings. — What is done with the sludge in Clinton?

Mr. Allardice. — Our sludge is so mixed with sand and gravel which fall into the furrows that we find it hard work to dispose of it to the farmers, and we carry it off and put it in the dump. The sludge we get in the sludge tanks we give to the farmers and find a very ready market for it. We rake it up into piles in the tanks and the farmers cart it off.

Mr. Hastings. — Is that done at the end of the season?

Mr. Allardice. — It is done during the whole season except, of course, in the winter, when it is frozen.

Mr. R. S. Weston. — I think it would be well at this point if some one would tell us briefly what the analytical character of the sewage in these places is. As I understand it myself, the sewage at Brockton is domestic, mixed with a very little shoe manufacturing waste. The sewage at Clinton is a textile waste, mixed with domestic sewage, and the sewages at Concord and Framingham are almost purely domestic. Perhaps Mr. Johnson could tell us about that.

Mr. W. S. Johnson. — The sewage at Brockton is a very strong domestic sewage containing some wastes from shoe factories. The sewage at Clinton contains a large quantity of wool scouring wastes. At Framingham spent dyes from the straw factories and from the Dennison Manufacturing Company

are discharged into the sewers, giving the sewage a distinct color. Sometimes the effluent from the Framingham filter beds is a bright red, at other times it is a brilliant green. The Concord sewage is strictly domestic.

Mr. L. Metcalf. — One question occurs to me which I should like to ask Mr. Bolling. Has any comparison been made of the cost of constructing and maintaining spare beds for use in draining the other beds in spring, having them idle during the winter, as compared with the cost of treating the beds without them? You said it was cheaper to drain off the beds on spare beds. I wondered if you had figured in the additional cost of building and maintaining those beds?

Mr. Bolling. — It is cheaper to do it in this way. On some of the beds the sewage reaches a depth of 18 in., and in the spring it would be practically impossible to get that absorbed into the bed; it would cost a large sum to rake it over until it was absorbed, and this would have to be done, because it would otherwise become a nuisance when the weather got warm. So we find that the best method is to draw it off on to fresh beds, where it is readily absorbed. Also, thus far, since the scheme was inaugurated we have succeeded in making considerable use of these beds during the winter months, even though they were left flat.

Mr. G. A. Carpenter. — Is the sludge at the Brockton plant turned on any special bed in the winter, or on the beds indiscriminately?

Mr. Bolling. — We have five or six beds that we use for sludge beds all the year round. These beds are cleaned five times during the year, but not during the winter. Sometimes the furrows in the sludge beds contain 10 in. of sludge in the spring.

Mr. Carpenter. — How do you get rid of the sludge in the spring? It won't dry out.

Mr. Bolling. — It holds from 40 to 45 per cent. of water, but there is no difficulty in getting it out of the bed.

Mr. H. P. Eddy. — I have said so much on these subjects that I hesitate to get up again. We don't use the furrowed bed, consequently I am a little bit out of joint with the sentiment of the meeting, I suppose. The reason we don't use the furrowed bed is because, in the first place, it costs something to furrow it. In the second place, running the crude sewage on, as we do, without any removal of suspended matter, except that taken out in the grit chamber, 0.3 cu.yd. per million gal., would give

an immense accumulation of sludge in the furrows and put the bed out of business. In the spring, when we clean the bed, it costs a great deal more to get the sludge out of the furrows than it would to remove it from the flat bed. In the third place, every time the surface of the bed is disturbed it mixes the organic matter which is in the sand and is not completely removed in cleaning with the comparatively clean sand below. I appreciate that all of these reasons are subject to discussion and differences of opinion, but my judgment is that the reason we have differences of opinion is largely because of differences in local conditions. We get, as a rule, more water through our filters in winter than in summer, which is another point on which we do not all agree, perhaps. But my impression is that the reason for that in our case is that we do not allow the frost to form to any great depth; perhaps 6 in. would be our limit, and that has certainly the effect of expanding the surface. The frost pushes the grains of sand on the surface, which are mixed more or less with organic matter, further apart and this lets the water through more easily. When the temperature is such that the surface of the bed is just frozen hard enough to drive a team on, without cutting through, the bed is very porous and will take a very large amount of water, and we usually avail ourselves of that opportunity to give it a pretty good-sized dose, 300 000 gal., I should say, to the acre, and in that way get rid of all the frost, and if there is an accumulation of snow, we get rid of that, or most of it, in one or two days. This disposes of the trouble from frost in the bed, which I classify as a different disease from the trouble with ice. The ice which forms on the surface of the bed, before the water penetrates through the sand, settles down, of course, as the water goes into the filter, and if there are no furrows to hold it up there is a tendency for it to freeze to the surface of the bed. To prevent this we rake the sludge on the surface of the beds into piles in the fall of the year, piles, I should say, about 6 in. high and approximately 12 in. in diameter and about 8 ft. from center to center. These piles serve to hold this layer of ice off the sand and to prevent it from freezing on to the surface of the bed, and with that assistance we have had practically no trouble from the ice freezing to the surface of the beds on those beds where sewage is distributed from four different points. This, I think, is a very important point to be considered in designing a filtering plant, to deliver the sewage from at least four points, and at the same time not so many points that it is delivered slowly and cools rapidly. The question of keeping

the bed free from the suspended matter of the sewage in the winter time is a somewhat troublesome problem, and that we deal with by putting a force of men at work just the minute there is an opportunity — that is, just the minute the weather conditions are right. We are favorably situated in this respect by having a force of men near by on another part of the work, and we simply shut down our filter-pressing plant and send the men down there for perhaps a couple of hours in the day, and in that way we are able to rake up the coarse material at such points as may be necessary almost every winter. That enables us to keep our filter fairly open and in good condition. These piles grow in the winter time due to that cleaning, so that in the spring we have 300 cu.yd. of material per acre to remove from the filters.

A Member. — What do you do with it?

Mr. Eddy. — We give the neighbors all they will take. Most of them are homeopaths and do not seem to take very large doses. All told, including sludge from chemical treatment, we get rid of from 3 000 to 5 000 cu.yd. a year. The rest of it, which amounts to about 35 000 cu.yd. more, we use for filling up low land and holes anywhere we can find them.

A Member. — May I inquire of Mr. Eddy whether there is not considerable acid in the Worcester sewage?

Mr. Eddy. — Well, there is a little sewage in the acid. The chairman has asked about descriptions of sewage. It occurred to me that a description of the sewage of Worcester would be brewery waste, shoddy mill waste, dye plant waste, a good deal of wool scouring, pickling liquids and acids, with a little sewage mixed in.

A Member. — How about the color of the effluent, Mr. Eddy?

Mr. Eddy. — Why, the coloring matter in the sewage is removed almost always by the filters, so that the water, as you see it flowing along is substantially free from any of the color of the dyes which were in it originally. In this connection I might state that the iron in the sewage comes through the filters somewhat changed, and, depending somewhat upon the condition of the filters, we get effluents containing almost no iron and effluents which are fairly loaded with the heavy red precipitate of oxide of iron, which, of course, affects the color. But only when the filter is very free, due to frost in the upper layer in the winter and to thorough cleaning in the summer, does the coloring matter in the original sewage pass through the filter without being removed. This is a very unusual occurrence.

A MEMBER. — I should like to ask Mr. Johnson if he has any explanation for the presence of the coloring matter which comes through the Framingham filter. As I understand it, the effluent there is considerably colored by dyes.

MR. JOHNSON. — I have no explanation to offer. It is possibly due to the nature of the dyes in the sewage.

THE CHAIRMAN. — I wonder if Mr. Woodfall will inform us about the operation of the plant at Gardner.

MR. WOODFALL. — At Gardner the beds are furrowed. I think the work is done very much as it is at Brockton. The furrows are made across the bed, and connected by cross-ditches. The ice rests on the ridges and little trouble has been experienced in freezing weather. In 1891, when the beds were first put in operation, they were not furrowed and considerable trouble was given by the ice freezing to the surface of the beds. At the plant in Andover which I constructed, corn is planted in the summer and when it is cut in the fall, the hills are left, and, as far as I am informed, it has given the least trouble of any plant I know of. In conversation with the superintendent three or four years ago, he told me that the beds had been raked or cleaned but once and then it was necessary only on account of flushing out the long inverted siphon through which the sewage passes on its way to the filter beds. As I understand it, the effluent is not as good as in a great many other places. I think, possibly, that Mr. Johnson might give a few points if he cared to. He is, perhaps, more familiar with present conditions than I am.

MR. JOHNSON. — I think the explanation of the fact that so little cleaning of the beds is necessary at Andover is that the solid matters are almost entirely removed from the sewage before it reaches the beds. In the first place, there is a septic action in the long siphon of which Mr. Woodfall has spoken, and then the sewage passes through a settling tank of considerable size as compared with the flow, which very effectually removes the solid matter. The sewage when discharged on the beds contains little solid matter and what it does contain is very finely divided; consequently, the beds never need raking, but a very poor effluent is produced.

A MEMBER. — I should like to ask Mr. Johnson if he has any explanation as to why the effluent is so poor.

MR. JOHNSON. — The experience in this state has been that septic sewage gives a very poor effluent. At Hopedale, Gardner and Andover, where septic sewage is applied to filter beds, the

purification is less complete than in those places where fresh sewage is applied. The purification would probably be better if the septic sewage were aërated, but under the conditions as they exist in Massachusetts the poorest effluents are obtained from filtering septic sewage.

Mr. Leonard Metcalf. — With reference to the Hopedale situation, I should like to ask Mr. Johnson, May it not be in part from the fact that the beds there are very shallow, that the effluent is so poor? He will recollect that when the beds were first constructed we were fooled completely by the character of the soil. We dug a large number of test pits considering the area of the beds, and took samples of the sand, which showed a free material, a suitable material for use. But when we came to make the excavations we found the area was a regular stone quarry, and it became necessary later on to cart material on to these beds. I have always had the feeling that upon the upper beds the work was being done by from 18 in. to 2 ft. of material. But, so far as I know, and Mr. Johnson will correct me if I am misstating the fact, we have had no comparative analyses of the effluent from different beds at that plant. I think it might be interesting to see whether or not there is any difference in the effluents from the different beds on account of the fact that the lower ones are of greater depth.

In the Hopedale plant the carting of sand on to the beds was viewed as a pure question of dollars and cents. We did not go any further in putting on suitable material than we felt we had to in order to secure satisfactory results.

Mr. Woodfall. — In the Andover plant the sub-drains were put usually at the depth of from 4 to 5 ft., and in some cases deeper. Perhaps half the area was underlaid with gravel which was not disturbed at all. Trenches were simply cut through the beds and the pipes laid in them. The other half was artificially made from material taken from a higher level. This, I think, will corroborate what Mr. Johnson says, that if you carry the septic action too far it makes no difference whether your bed is deep or shallow; you are likely to have imperfectly purified effluents.

Mr. C.-E. A. Winslow. — I should like to say that the experiments we have made at the Technology Experiment Station strikingly corroborate Mr. Johnson's observations on this point. We have, for a period of about a year, filtered crude Boston sewage and septic effluent on sand filters under strictly comparable conditions and have found that the effluent from

the combined septic and sand process is uniformly poorer than that from the sand process alone. The two filters were operated at the same rate and the surface of that which took septic effluent was somewhat easier to care for than that which took crude sewage, although the difference was not marked. On one occasion the septic effluent clogged the filter very rapidly by a deposit of finely divided sulphide of iron, as we supposed. It was evident at all times that without some special preliminary process of aëration the septic treatment produced an effluent which would not nitrify readily.

There is one other point to which I should like to call attention which has not been brought up in this discussion; that is the variation in the chemical composition of the effluent at different seasons. No doubt the most important effect of winter is that upon which the speakers have dwelt, the clogging of the filters, with the consequent practical difficulties in operation. There is also, however, a direct biological action of low temperature which interferes with the activity of the nitrifying organisms. In the report on the purification of Boston sewage, just issued by the geological survey as Water Supply Paper No. 185, Mr. Phelps and I have compared the analytical results obtained at Brockton and Lawrence for the different months in the year, and the ratios there calculated show a very regular seasonal curve, the free and albuminoid ammonia and the oxygen consumed being highest in February at Lawrence, and in March at Brockton, while the nitrates reach a minimum at the same time. The maximum monthly deviation amounts to about 100 per cent., the worst monthly averages containing twice as much organic matter as the yearly average. Of course it is a well-known fact that the effluents from sand filters, although generally clear, are much more offensive in winter than in summer, but the exact extent of the damage as shown in this way is of some interest.

R. S. Weston. — Is it not possible that what we call over-septic treatment produces other changes in the character of the sewage than what we now believe? We aërate septic sewage to make it more applicable to the disposal beds. Do we do this to remove the toxins or to break down the colloidal or semi-soluble matter produced in the septic tank? Have we data enough to say definitely that there are enough toxins produced in septic tanks to interfere with the action of aërobic bacteria in the sewage disposal beds? Have we any more reason to say so than that colloids are the interfering bodies? This query seems

reasonable, especially in view of the paper presented at our last meeting by Mr. Eddy, in which he showed that long agitation and contact between suspended matter in sewage and the sewage itself renders a large part of that suspended matter semisoluble, so that after passing through the septic tank reprecipitation takes place, especially in the sewage disposal bed, which interferes with the efficiency of the latter. Is one position any more tenable than the other, in the light of our present data?

Prof. L. P. Kinnicutt. — I will say a word in regard to the removal of the color from sewage containing dye wastes. There is a difference in the action on different colors. There is rose aniline, which is removed very easily. Aniline black is very stable. If logwood is used, and the sand contains iron, then you get the same thing as ink, which remains in the effluent. I think it depends entirely on the kind of dyes used. Magenta or rose anilines, or aniline blues are easily taken out, while aniline black, or logwood mixed with iron in the sand, is very stable. It is merely a question of the kind of dye that goes into the sewage.

The Chairman. — One or two years ago Mr. Goodnough made a tour of the sewage plants during the winter. Will you give us an account, Mr. Goodnough, of what you observed at that time, especially at those plants which have not been touched upon this evening?

Mr. X. H. Goodnough. — I think what is true of the plants mentioned by the speakers to-night is true of most of the others. The plant at Pittsfield is, perhaps, in the coldest climate of any in the state. I visited that, not in the last year, but quite recently. That is operated in much the same way as the plants at Clinton and Brockton. The method in general followed everywhere is to ridge the beds in winter, or else to leave the beds with the corn hills after the corn is cut, and usually very little difficulty is found in disposing of the sewage through the winter season. It was a noticeable fact that during the very severe winter of 1903–1904 there was a great falling off in the efficiency of the purification at all of the filtration works. I think that practically without exception a greater amount of free ammonia and organic matter appeared in the effluent and a larger amount of iron. This was true of the new beds as well as of beds which had been in use a good many years. There was another very cold winter following that one, and the poorer effluents continued for two years. In most of them there has been some improvement since. At a good many of the smaller places the beds are

left flat in winter. If the beds are so arranged that a large dose can be applied very quickly, the experience seems to show that the plan is a satisfactory one. On the other hand, where the dose cannot be applied quickly, of course the tendency is for the beds to freeze up at points remote from the outlets. There is one very interesting filtration area which has not been mentioned to any great extent, and that is the one at Gardner. At Gardner the filter beds are small in area in proportion to the quantity of sewage, which runs up to from 250 000 to 300 000 gal. per acre per day, and at times to nearly double those quantities. The sewage is put through a very large tank, and afterwards, at times, through coke strainers and then applied to the filter beds. The filter beds are shallow and the quality of the effluent is not as good as in a good many of the other areas. Whether this is due to the fact that the sewage decomposes before application, — it is practically a septic sewage, — or to the character of the filtering material, or to the thinness of the beds or to the excessive quantity applied, I am unable at present to say. It may be classed with those beds which receive septic sewage and which, as a rule, give a poorer effluent than beds to which fresh sewage is applied.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1907, for publication in a subsequent number of the JOURNAL.]

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVIII. FEBRUARY, 1907. NO. 2.

THE MECHANICS OF REINFORCED CONCRETE.

BY C. B. WING, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, December 7, 1906.]

IN the past practical applications of the theoretical principles of mechanics have been largely confined to the design of structural members built of homogeneous materials, and the methods of making such applications are familiar to structural engineers. Recently the addition of metal to concrete for the purpose of increasing its power of resisting tensile stresses has come to be the practice in a large class of structural work. It is necessary, therefore, for the designer to consider the methods of applying the elementary fundamental principles of mechanics to the design of structural members built of non-homogeneous materials. This is a matter of some complexity, and on this account many empirical methods of avoiding the difficulties encountered have been suggested from time to time in the technical literature of the past few years. The writer believes that the use of empirical formulæ is unnecessary and in untrained hands may lead to dangerous results;* therefore, formulæ based upon accepted theoretical and experimental laws of the action of elastic materials under stress have been developed for a few of the cases arising in the design of reinforced concrete, and methods for their ready solution indicated.

The subject will be considered under three heads as follows:

Development of formulæ.

Principles and methods to be used in application of formulæ.

* Trans. Am. Soc. C. E., Vol. lvi, p. 390.

Comparison of results obtained by formulæ with results of tests.

Development of Formulæ.

The discussion will be limited to cases of direct tension, compression and simple cases of flexure.

Case I. *Simple tension or compression.* Concrete bar reinforced with metal bars imbedded in the concrete.

Required: The distribution of stress in the cross section of the bar between the concrete and metal.

Assumptions: (*a*) That the adhesion between the metal and concrete is perfect. (*b*) That there are no initial stresses. (*c*) That the maximum stresses are within the elastic limits of the materials.

Let P = Total load carried by the bar.
P_s = Portion of load carried by the metal.
P_c = Portion of load carried by the concrete.
A = Total area of cross section of bar.
A_s = Area of metal.
A_c = Area of concrete.
S_s = Stress per unit of area in metal.
S_c = Stress per unit of area in concrete.
E_s = Modulus of elasticity of metal.
E_c = Modulus of elasticity of concrete.
$n = \frac{E_s}{E_c}$ = The ratio of the respective moduli of elasticity of metal and concrete.
l = Length of bar.

As the load P is gradually applied, the bar is extended or compressed (*i. e.*, the metal and concrete are extended or compressed equally) an amount λ. From the ordinary theory of the action of elastic materials within the elastic limit,*

$$\lambda = \frac{P_s l}{A_s E_s} = \frac{P_c l}{A_c E_c}. \qquad (1)$$

From definition,

$$P = P_c + P_s = A_c S_c + A_s S_s. \qquad (2)$$

Substituting in (1) and solving,

$$P_s = \frac{A_s E_s}{A_c E_c + A_s E_s} \cdot P. \qquad (3)$$

* Merriman: Mechanics of Materials, p. 8, edition 1900; p. 24, edition 1905; Church: Mechanics of Materials, p. 209.

$$P_c = \frac{A_cE_c}{A_cE_c + A_sE_s} \cdot P. \qquad (4)$$

Dividing (3) by (4),

$$\frac{P_s}{P_c} = \frac{A_sE_s}{A_cE_c}. \qquad (5)$$

But,

$$\frac{P_s}{P_c} = \frac{A_sS_s}{A_cS_c}.$$

Therefore,

$$\frac{S_s}{S_c} = \frac{E_s}{E_c} = n. \qquad (6)$$

That is, the unit stresses in the steel and concrete are to each other as the moduli of elasticity of the respective materials; or, in other words, the unit stress in the steel of a reinforced concrete bar subjected to external forces of tension or compression is n times the unit stress in the concrete surrounding it.

Substituting the value of S_s or S_c from equation (6) in equation (2),

$$\left.\begin{aligned} P &= (A_c + nA_s)S_c \\ \text{or,}\quad P^1 &= \left(\frac{A_c}{n} + A_s\right)S_s \end{aligned}\right\} \qquad (7)$$

By assigning safe values to S_c and n or S_s and n in any given case, values of P and P^1 can be determined. The safe load for the column or bar will be the smaller of these two values. Conversely, equation (7) may be written,

$$A_c + nA_s = \frac{P}{S_c} \text{ or } \frac{nP}{S_s}. \qquad (7)'$$

Substituting safe values for S_c or S_s and n as before, the sum of the areas of the two materials required to carry a given load P can be determined. The safe area will be the larger of these two values.

Case II. *Flexure.* Three classes of problems arising in the use of reinforced concrete for beams will be considered.

(a) Symmetrical reinforced concrete beams with the reinforcing metal symmetrically placed with respect to the axes of the cross section of the beam.

(b) Symmetrical reinforced concrete beams with the reinforcing metal in the tension flange only.

(c) Unsymmetrical reinforced concrete beams with the reinforcing metal in the tension flange only.

(a) Symmetrical beams symmetrically reinforced.

Required: Distribution of stresses in the cross section of the beam and the moment of these stresses about the neutral axis, *i. e.*, " moment of resistance " of the section.

Assumptions: In addition to those given in Case I there will be:

(*d*) That the modulus of elasticity of concrete is the same for both tension and compression, and that within the limits of safe stress for the material it is practically constant.

(*e*) That Hooke's law — stress proportional to strain — is applicable to the distribution of stress within the limits of safe stress for the materials.

From equation (6) the unit stress in the metal at any point of the cross section is found to be n times the unit stress in the adjacent concrete. The moment of resistance of the metal will, therefore, be n times that of the same amount of concrete.

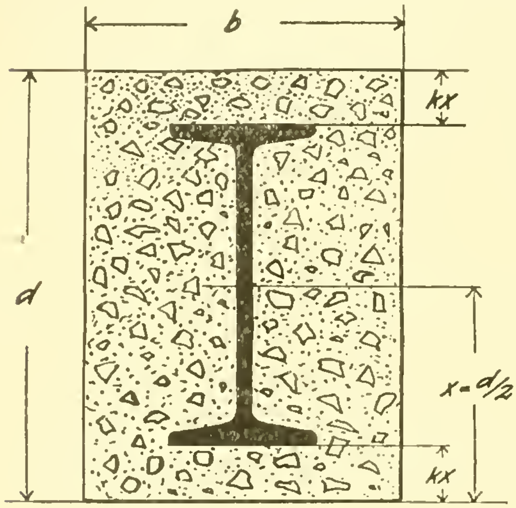


Fig. 1.

In Fig. 1 let I = the moment of inertia of the rectangle bd. I_s = the moment of inertia of the metal. The moment of resistance of the internal horizontal forces will be according to the ordinary theory of flexure,*

$$\frac{S_c(I - I_s)}{c} + \frac{nS_c(1 - k)I_s}{c - kc} = M$$

in which $c = x = \frac{d}{2}$. Reducing and simplifying there results,

$$\frac{S_c\,[I + (n - 1)I_s]}{c} = M. \quad (8)$$

The method of using equation (8) for the solution of problems is the same as for ordinary cases of flexure and needs no

* Merriman: Mechanics of Materials, p. 51; Church, Mechanics of Materials, p. 249.

further discussion. Equation (8) applies equally well to cases similar to that shown in Fig. 2. The maximum unit stress in the metal in either case is $S_s = nS_c (1 - k)$. If $n = 10$ and $S_c = 300$, the unit stress in the metal is less than 3 000 lb. per sq. in. As the ordinary safe unit stress for metal is 16 000 lb. per sq. in., the use of metal in concrete beams of this form is decidedly uneconomical unless the design is such that the concrete can be applied to the steel after the structure has received a large portion of the load it is expected to carry.

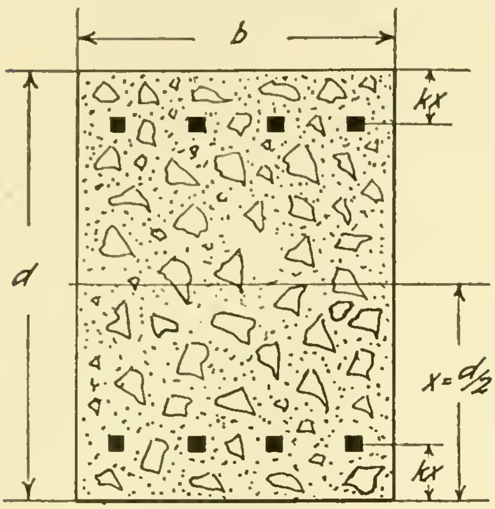


Fig. 2.

(b) **Symmetrical beams unsymmetrically reinforced.**

The requirements and assumptions are the same as for beams of class (a). Two conditions of stress will be considered; (1) The action of the beam up to the point of tensile rupture of the concrete; (2) the action of the beam after tensile rupture of the concrete has taken place up to the point of failure of the concrete in compression or to the elastic limit of the steel in tension.

(1) Considering the tensile strength of the concrete available for carrying stress.

The ordinary theory of flexure requires that the sum of the horizontal forces above the neutral axis shall equal the sum of the horizontal forces below the neutral axis of the cross section. As the tensile strength of concrete is less than the compressive strength, in order to develop the strength of the concrete as fully as possible it is desirable to have the neutral axis of the beam nearer the bottom than the top. To bring about this result with a beam composed entirely of concrete, and at the same time meet the requirements of the theory of flexure as stated above, the beam should have a cross

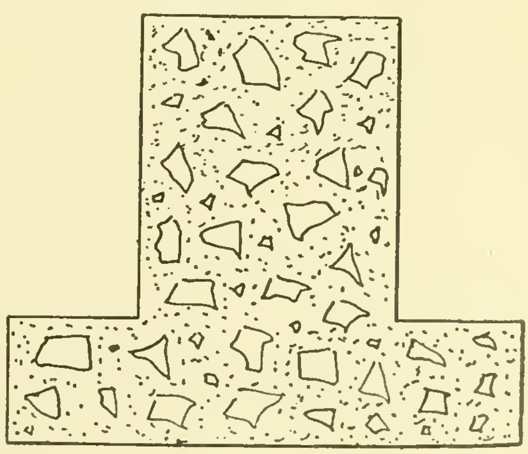


Fig. 3.

section as shown in Fig. 3, or in the cross section shown in Fig. 4, a certain amount of metal area A_s must be provided below the neutral axis.

Let Fig. 4 represent the distribution of the stresses in the

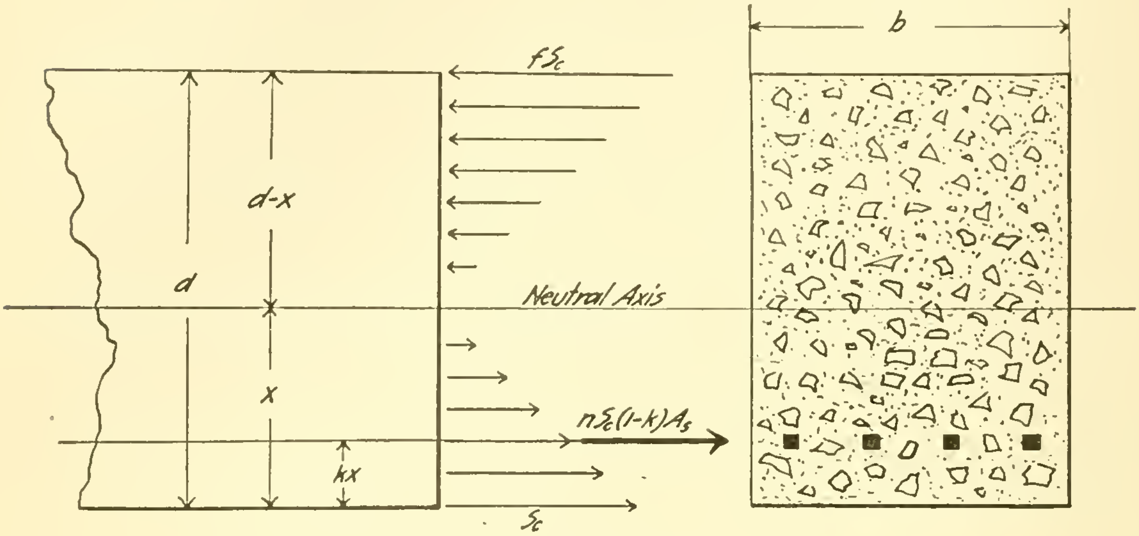


Fig. 4.

cross section of an unsymmetrically reinforced concrete beam in flexure.

Let l = Span of beam.

b = Width of beam.

d = Depth of beam.

x = Distance of neutral axis from bottom of beam.

kx = Distance of center of metal reinforcement from bottom of beam.

A_s = Sectional area of metal; usually small when compared with the area of the concrete.

$n = \frac{E_s}{E_c}$ = Ratio of respective moduli of elasticity of metal and concrete.

f = Ratio of maximum compressive unit stress of concrete to maximum tensile unit stress.

S_c = Maximum tensile unit stress in concrete.

S_s = Tensile unit stress in metal.

M = The moment of resistance of the cross section.

The position of the neutral axis will vary as f varies and for any given value of f will be determined by the proportion (see Fig. 4),

$\frac{x}{S_c} = \frac{d-x}{f\,S_c}$, from which is derived the equation,

$$x = \frac{d}{f+1}. \tag{9}$$

The unit stress S in the concrete surrounding the metal is given by the proportion,

$$\frac{S_c}{x} = \frac{S}{x(1 - k)}.$$

$\therefore S = S_c(1 - k)$, and from (6) the unit stress in the metal is

$$S_s = \frac{E_s}{E_c} S = nS_c(1 - k). \qquad (10)$$

The algebraic sum of the horizontal stresses acting on the cross section is, therefore (see Fig. 4),

$$\Sigma SdA = \frac{fS_cb(d - x)}{2} - \frac{S_cbx}{2} - nS_c(1 - k)A_s.$$

Equating this sum to zero, substituting the value of x from (9) and solving, there results the equation,

$$A_s = \frac{(f - 1)bd}{2n(1 - k)},$$

or,

$$f = \frac{nA_s}{bd} 2(1 - k) + 1. \qquad (11)$$

The moment of these stresses about the neutral axis gives the moment of resistance of the cross section as follows:

$$M = \frac{fS_cb(d - x)}{2} . \frac{2}{3}(d - x) + \frac{S_cbx}{2} . \frac{2}{3} x + nS_c(1 - k)A_s . x(1 - k).$$

Substituting the values of x and A_s from (9) and (11), there results the equation,

$$M = S_cbd^2 \cdot \left[\frac{f^3 + 1}{3(f + 1)^2} + \frac{(1 - k)(f - 1)}{2(f + 1)}\right]. \qquad (12)$$

It should be noted that this equation is similar in form to the ordinary flexure equation $M = \frac{SI}{c}$, the quantity $bd^2[\ ]$ being the section modulus or $\frac{I}{c}$ of the beam, in which

S = the unit stress in the outer fiber.
I = the moment of inertia of the cross section.
c = the distance of the outer fiber from the neutral axis of the cross section.

Theoretically the above formulæ will correctly represent the action of reinforced concrete beams up to the point of failure

of the concrete in tension, provided that point and its elastic limit are coincident. The error, if any, in this assumption is small and practically may be neglected.

(2) Neglecting the tensile strength of the concrete.

With tensile strength in the concrete destroyed by flaws or stresses beyond the point of tensile rupture, the quantity $\frac{S_c bx}{2}$ drops out of the summation of the horizontal stresses acting on the section, and equation (11) becomes

$$A_s = \frac{f^2}{2n(1-k)\ (f+1)}\ bd;$$

or,

$$f = \frac{nA_s}{bd}(1-k) \pm \sqrt{\frac{nA_s}{bd}(1-k)\left[\frac{nA_s}{bd}\cdot(1-k) - 2\right]} \qquad (13)$$

and similarly equation (12) becomes

$$M = fS_c bd^2\left[\frac{f^2}{3(f+1)^2} + \frac{f(1-k)}{2(f+1)^2}\right]' \qquad (14)$$

Equation (14) may be readily changed by substituting for S_c its value from equation (10). Thus,

$$M = S_s bd^2\left[\frac{f^3}{3n(f+1)^2\ (1-k)} + \frac{f^2}{2n(f+1)^2}\right]'' \qquad (15)^*$$

(c) **Unsymmetrical reinforced concrete beams unsymmetrically reinforced.** The T beam or ribbed floor slab is the principal beam in practical use falling under this classification. Formulæ for designing this type of beam may be derived in a manner similar to that used in the previous cases. Such formulæ are more complicated in form and cannot be so readily solved graphically. To consider a wide thin floor slab as part of the compression flange of the supporting beam is questionable from a practical standpoint. In the present state of knowledge of the action of such beams, and considering the danger of lack of continuity in their construction, the conservative engineer would design the rib to carry the load and consider the slab as transferring the floor load from each side to the rib. The portion of the floor slab directly over the beam may be considered as part

* Since the above was written Professor Merriman has proposed a formula derived in a similar manner, considering a portion of the tensile stresses as always available for carrying stress. The results obtained by such a formula would not vary greatly from those obtained by use of formula (12).

of the beam if careful provision is made for its construction at the same time that the remainder of the beam is laid. For the above reasons the formulæ for this case will not be presented at this time.

Principles and Methods to be used in Application of Formulæ.

Equations (7) and (12) are proposed for use in designing reinforced concrete, and with their various modifications are applicable to most of the cases arising in practice. No originality is claimed for these formulæ other than the similarity of the beam formulæ to the formulæ in use for beams of homogeneous materials, and the ease with which the section modulus can be obtained by use of diagram or tables. Equation (7) is applicable to cases of direct tension or compression and equation (12) with the other subordinate or similar equations to ordinary cases of flexure. These equations involve the loads to be carried, certain constants the values of which depend upon the physical properties of the materials supporting the loads, and the cross-sectional area of these materials. The loads to be carried and the physical properties of the materials to be used in any given case being known, the required cross-sectional areas of the materials can be determined by numerical substitution in the proper formula.

The loads to be carried depend upon the position of the member to be designed in the structure of which it is a part and are usually expressed as so many pounds or tons of force acting in the direction of the longitudinal axis of the member, in cases of direct tension or compression, or as so many inch-pounds or foot-tons of bending moment if the member to be designed is subjected to flexure. The method of obtaining these forces and moments is not a part of the present discussion and they, therefore, may be assumed as known quantities in any given case.

The physical properties of the various kinds of metal available for reinforced concrete construction are readily determined and for any given material they are reasonably constant. Concrete, on the other hand, is variable in composition and the designer is confronted with a large mass of conflicting data regarding the physical properties of this material. It is not necessary to the present discussion to go into an extended investigation of the experimental data concerning the physical properties of concrete. The object of the discussion is to present a method by which safe and economical designs can be readily obtained provided the loads to be carried are accurately known and con-

servative values of the physical properties of the materials used are assumed. It is not out of place, however, to indicate what values of the physical properties of the materials are conservative. Thus an inspection of equation (7) shows that one unit of sectional area of metal in a reinforced concrete bar is equivalent to n units of concrete. The right-hand term of equation (7), which gives the load P a given bar can carry, varies directly as n, the ratio of the moduli of elasticity of the materials, and as S_c, the tension unit stress for concrete. Therefore, low values of these quantities are conservative. A low value of n is obtained by the assumption of a low value of the modulus of elasticity of the reinforcing metal and a *high* value of the modulus of elasticity of the concrete. This latter point is of great importance and should be carefully considered in choosing physical constants for reinforced concrete designs.

In recent discussions of reinforced concrete design much emphasis has been laid upon the fact that the elastic limit of the metal determines the ultimate strength of a reinforced concrete beam. In determining the safe unit stresses to be used in designing steel structures more and more attention is rightly being paid to the elastic limit of the metal as the real measure of the maximum stress the material will stand without failure of the structure, the ultimate or breaking strength of the material being considered as relatively unimportant. In like manner the point at which the concrete in reinforced concrete construction fails in tension, and *not* the elastic limit of the metal, is probably the real measure of the maximum stress to which the member should be subjected without endangering the safety of the structure of which it forms a part. This is especially true if the concrete is assumed to protect the metal from excessive heat or corrosion.

The great advantage of reinforced concrete construction is that the approximate strength and cost of a metal structure is obtained with the durability and heat resisting qualities of masonry. If, however, the design is such that cracks are allowed to form, as they surely do if the stresses exceed the tensile strength of the concrete, it is doubtful if the qualities of durability and fire-proofness are obtained. If these qualities are not obtained the chief advantage of the combination of the materials is lost.* The design of reinforced concrete structures should, therefore, be based upon the assumption of conservative

* *Engineering News*, Vol. lv, p. 291. Ninety-one cracks observed in 13 beams on application of *working* load.

values of the moduli of elasticity of the materials, and maximum stresses in excess of the ultimate strength of the concrete in tension should be avoided.

An acceptance of the above principle greatly simplifies the work of the designer, because in the majority of cases it renders unnecessary lengthy and involved considerations of shearing stresses and adhesions between metal and concrete At least in the design of reinforced concrete beams consideration of these subsidiary questions occupies the same place that consideration of shearing stresses occupies in the design of wooden beams; that is, the main proportions are determined by the theory of flexure, and certain special cases are afterward investigated to determine their ability to resist stresses other than those due to simple flexure.

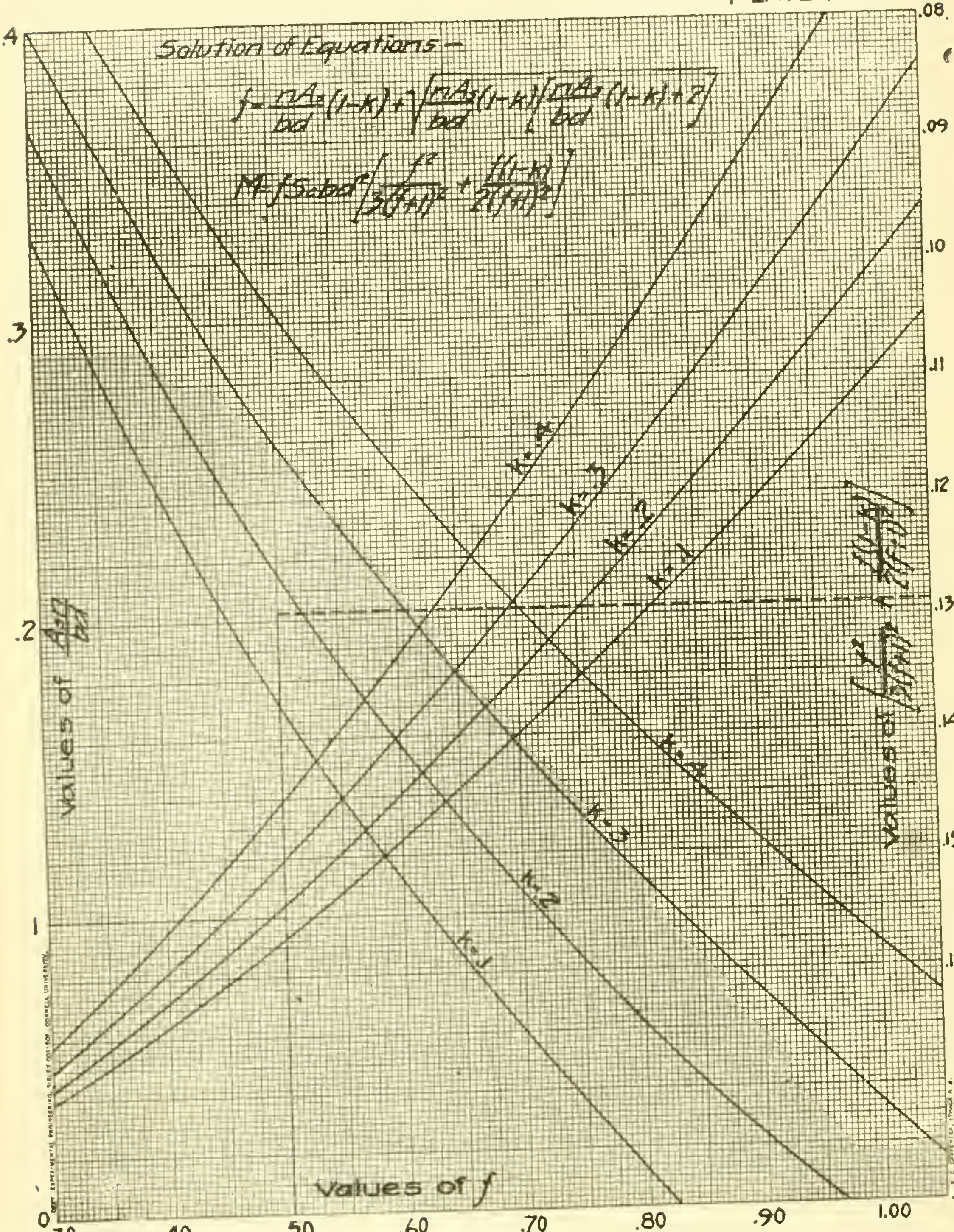
The method of using equation (7) for the design of reinforced concrete bars or columns subjected to direct tensile or compressive stresses needs no further explanation.

If conservative values of S_c and n are assumed the results obtained by substitution in the proper formula should be practical and safe, provided the ratio of the length to the least diameter of columns does not exceed 12. Special cases involving ratios greater than this should be designed by practical rather than theoretical considerations.

The metal in reinforced concrete carries per unit of area n times the stress in the adjacent concrete. The use of metal, therefore, in any given case to carry compressive stresses will not be economical unless its cost per cubic unit is less than n times the cost of a cubic unit of concrete. With steel at 2 cents a pound, and concrete at 30 cents a cubic foot, the cost of steel per cubic unit will be 32 times the cost of concrete per cubic unit. The value of n would have to be 32 for the cost of carrying a given stress by steel or concrete to be the same. An examination of experimental data shows the probable value of n even in extreme cases to be less than 16. It is safe to say, therefore, that measured by its stress-carrying power the steel in a reinforced concrete column costs twice as much as an equivalent amount of concrete. The use of concrete with longitudinal reinforcement subjected to direct compressive stresses is, therefore, uneconomical and not justified unless the concrete can be applied after the metal is under stress, and in such cases the metal should be designed of sufficient strength to carry all the loads and the concrete treated merely as a protective coating. The economical use of reinforced concrete is thus shown to be

confined to that class of masonry structures in which it is impractical to design them so that all tensile stresses are avoided. In the majority of such cases the tensile stresses are due to

PLATE II.



beam action, and their probable amount and intensity can best be determined by the application of the ordinary theory of flexure.

Equation (12) and its subsidiary and modified forms are

proposed for the investigation of the distribution of stresses in structures of this character and inversely for designing reinforced concrete beams to resist safely given external forces. An examination of the right-hand portion of equation (12) shows it to be of the same general form as the equation for the moment of flexure for simple beams. The quantity $bd^2[\ ]$ as previously stated takes the place of the expression $\frac{I}{c}$ or section modulus in the ordinary flexure formula $\frac{SI}{c} = M$. The method of using equation (12) for designing beams is, therefore, simple and well known as soon as the value of the quantity inside the bracket is determined. Discussion of the method of applying this equation to the design of beams will, therefore, be confined to the determination of this quantity.

Preliminary to a discussion of this point it will be necessary to consider the factors influencing the amount of steel reinforcement to be used in the tension flanges of a reinforced concrete beam. As shown in the discussion of columns, for the purpose of carrying stress, steel in reinforced concrete is at least twice as expensive as an equivalent amount of concrete; and if concrete could be relied upon to carry tensile stresses safely, the use of steel in combination with it could not be justified economically. The determination of the amount of steel reinforcement to be used in the tension flange of a reinforced concrete beam should, therefore, be based on data obtained from experiment and practical use and is not a subject for theoretical investigation.

The amount of steel used in the tension flange of a reinforced beam is usually expressed as a percentage of the total area of the cross section. Referring to equation (11) it is seen that if A_s is expressed as a certain percentage of bd, n and k are the only other quantities contained in the right-hand portion of that equation. The method for assuming a value of n has already been stated. The determinaton of a proper value of k is best obtained by trial designs. In practical designs its range of values is small and the second trial usually determines the proper value for a given case with sufficient accuracy.

For economy the metal should be as near the lower surface of the beam as consistent with protection of the metal from corrosion and proper adhesion between metal and concrete.

The section modulus of a reinforced concrete beam corresponding to a given value of $\frac{M}{S_c}$ is, therefore, obtained, as follows:

Values of n, A_s and k are assumed, and the corresponding value of f from equation (11) determined; this value is then substituted in the bracket of equation (12), giving the coefficient of bd^2 to be used in completing the section modulus. The determination of the required dimensions of the beam from this point is the same as for ordinary beams of timber or other homogeneous material. Numerically this is a long and tedious process, comparable to the numerical determination of the section modulus of a steel I beam. Plates I, II and III, however, give ready graphical solutions of the equations for the various cases under consideration.

Plate I is applicable to the solution of problems in which the tension in the concrete is taken into consideration. Thus, to give a direct illustration, for a given case let A_s be assumed equal to $\frac{1}{100}bd$, n equal to 10 and k equal to 0.2.

Entering Plate I on the left-hand ordinate at a value of

$$\frac{A_s n}{bd} = \frac{\frac{1}{100}bd \times 10}{bd} = 0.1,$$

and moving horizontally to the right until the diagonal line corresponding to a value of $k = 0.2$ is intersected, the value of $f = 1.16$ is found on the horizontal scale at the bottom of the sheet vertically beneath this point; then following this vertical line up until it intersects the diagonal line at the top of the sheet corresponding to the value of $k = 0.2$, the value of the [ ] = 0.213 of equation (12) is found on the vertical scale at the right side of the plate horizontally to the right of this point. Similar values may be obtained from Plates II and III in the same manner.

The method of using equations (12), (14) and (15) and Plates I, II and III for determining the cross section necessary to resist the action of an external bending moment will be more fully illustrated by the solution of the following examples:

Example 1. Required, the cross-sectional area of a rectangular reinforced concrete beam to resist safely the action of an external bending moment of 120 000 in.-lb.

Assume $S_c = 300$ lb. per sq. in.

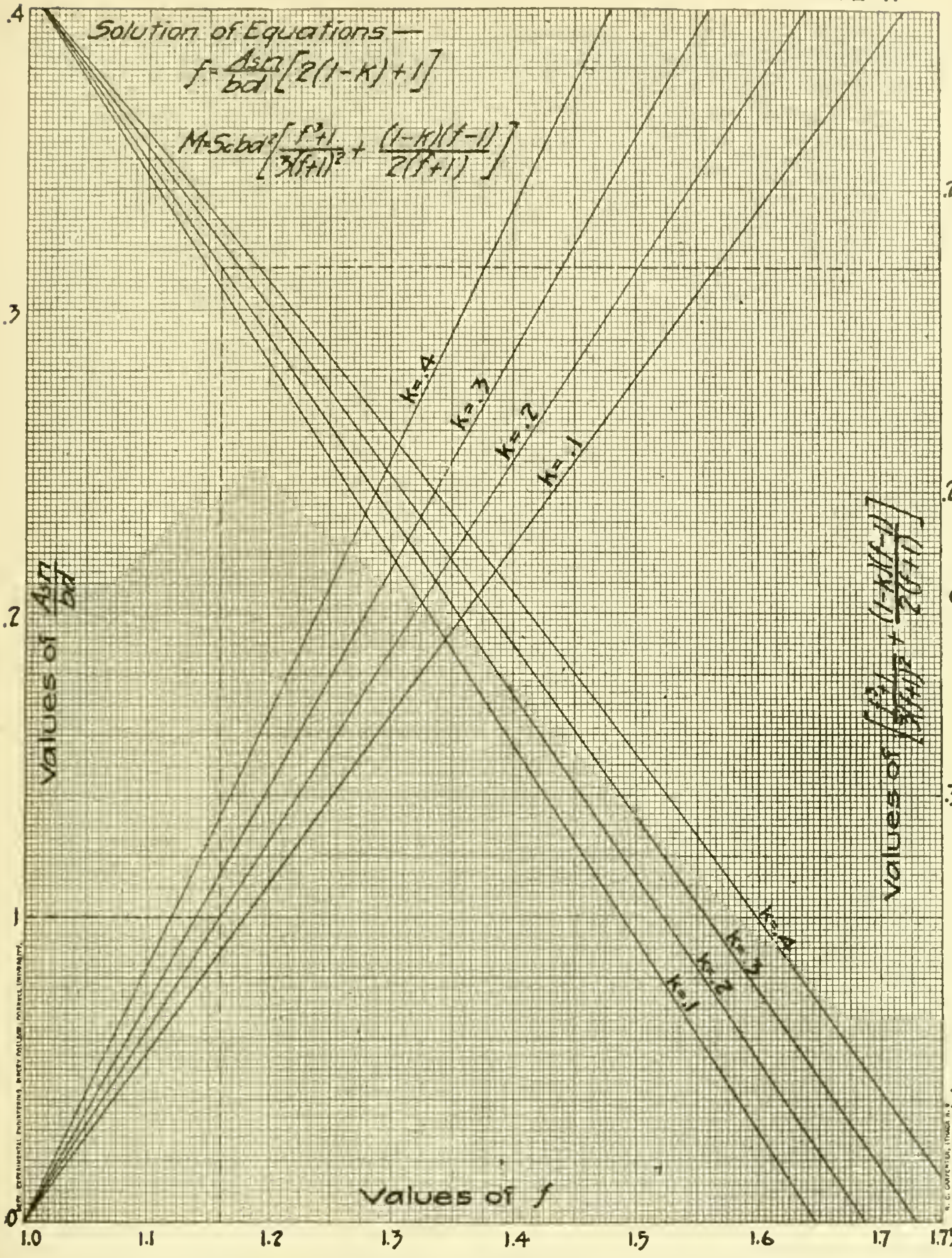
$n = 10$

$k = 0.2$

$A_s = 0.5$ per cent. bd.

From these $\frac{A_s n}{bd} = 0.05$.

PLATE I.



Substituting in equation (12), the required section modulus is found to be

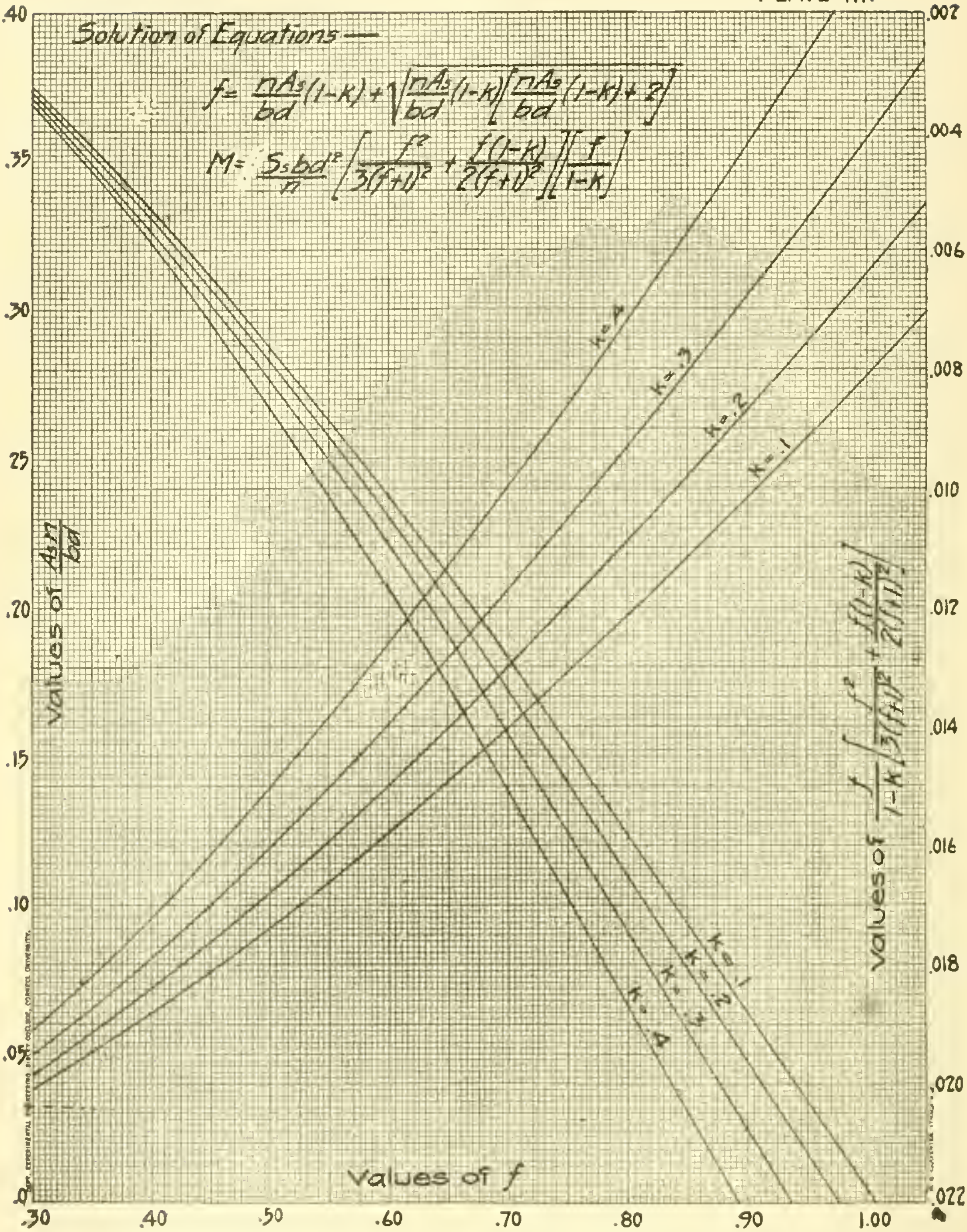
$$bd^2\,[\;] = \frac{120\,000}{300} = 400.$$

From Plate I, by methods previously indicated, the value of the [ ] = 0.190 is found. This gives

$$bd^2 = \frac{400}{0.19} = 2\,100 \text{ cu. in.},$$

from which, if $b = 12$ in., the value of $d = 13.25$ in. is found.

PLATE III.



Substituting this value, and the value of $f = 1.08$ obtained from Plate I in equation (9), there results the value

$$x = \frac{13.25}{1.08 + 1} = 6.36 \text{ in.},$$

and $kx = 0.2 \times 6.36 = 1.27$ in., a value that is satisfactory for the design in question, and consequently the assumed value of $k = 0.2$ is found to have been correct. The unit stress in the steel is found by substitution in equation (10) to be

$$S_s = 10 \times 300\ (1 - 0.2) = 2\ 400 \text{ lb. per sq. in.}$$

and the maximum unit compression stress in the concrete is

$$fS_c = 1.08 \times 300 = 324 \text{ lb. per sq. in.}$$

The above solution of the problem is based on the assumption that the tensile strength of the concrete is available for carrying stress.

The design must now be tested to determine the maximum stresses in the concrete and steel if at the point of maximum external moment the tensile strength of the concrete is destroyed. This investigation can be made by use of equations (13), (14) and (15) and their solution is made easy by the use of Plates II and III. Substituting in equation (14) by use of Plate II,

$$fS_c = \frac{M}{bd^2[\ ]'} = \frac{120\,000}{2\,100 \times 0.0935} = 611 \text{ lb. per sq. in.,}$$

and substituting in equation (15) by use of Plate III,

$$S_s = \frac{M}{bd^2[\ ]''} = \frac{120\,000}{2\,100 \times 0.0038} = 15\,000 \text{ lb. per sq. in.}$$

As these values are safe the design can be considered a fairly satisfactory one. It should be noted, however, that a complete failure of the concrete in tension would change the unit stress in the metal from 2 400 lb. per sq. in. to 15 000 lb. per sq. in., thus increasing the unit elongation approximately six times. This in beams having the maximum moment extending over a considerable length would, undoubtedly, cause some opening of hair cracks and might cause ultimate failure of the metal if the same is ever exposed to corrosion or heat. The results of the above computation at least suggest the necessity of experimental investigation along the lines of determining the effect of hair cracks on concrete as a protective coating.

In order to more clearly illustrate the range of use of the formulæ and plates another application will be made.

Example 2. Find the capacity of the beam of the previous problem when reinforced with 1.5 per cent. of metal instead of 0.5 per cent. This gives

$$\frac{A_s n}{bd} = \frac{\frac{1.5}{100} bd \times 10}{bd} = 0.15.$$

Substituting in equation (12) by use of Plate I with $k = 0.225$,

$$M = 300 \times 2\,100 \times 0.2325 = 146\,500 \text{ in.-lb.}$$

Substituting the value of $f = 1.235$ obtained from Plate I in equation (9), there results,

$$x = \frac{13.25}{1.235 + 1} = 5.93 \text{ in.}$$

and

$$kx = 0.225 \times 5.93 = 1.33 \text{ in.},$$

a value that very nearly corresponds to the value obtained in the previous case, showing the assumed value of $k = 0.225$ to have been approximately correct.

Substituting in equation (10), the unit stress in the steel is found to be

$$S_s = 10 \times 300(1 - 0.225) = 2\,325 \text{ lb. per sq. in.},$$

and the maximum compressive unit stress in the concrete is

$$fS_c = 1.235 \times 300 = 370 \text{ lb. per sq. in.}$$

Testing for the unit stresses on failure of the concrete in tension there results by use of Plates II and III,

$$fS_c = \frac{146\,500}{2\,100 \times 0.1395} = 500 \text{ lb. per sq. in.}$$

and

$$S_s = \frac{146\,500}{2\,100 \times 0.011} = 6\,340 \text{ lb. per sq. in.}$$

These values are much less than those obtained in the previous case, showing less danger from the opening of serious cracks.

The formulæ proposed are thus shown to be readily applicable to the design of reinforced concrete beams whether the tension in the concrete is considered or not, and have the advantage of enabling the designer to obtain the stresses in the concrete and steel, with equal ease, for either assumption.

Comparison of the Results obtained by Formulæ with the Results of Tests.

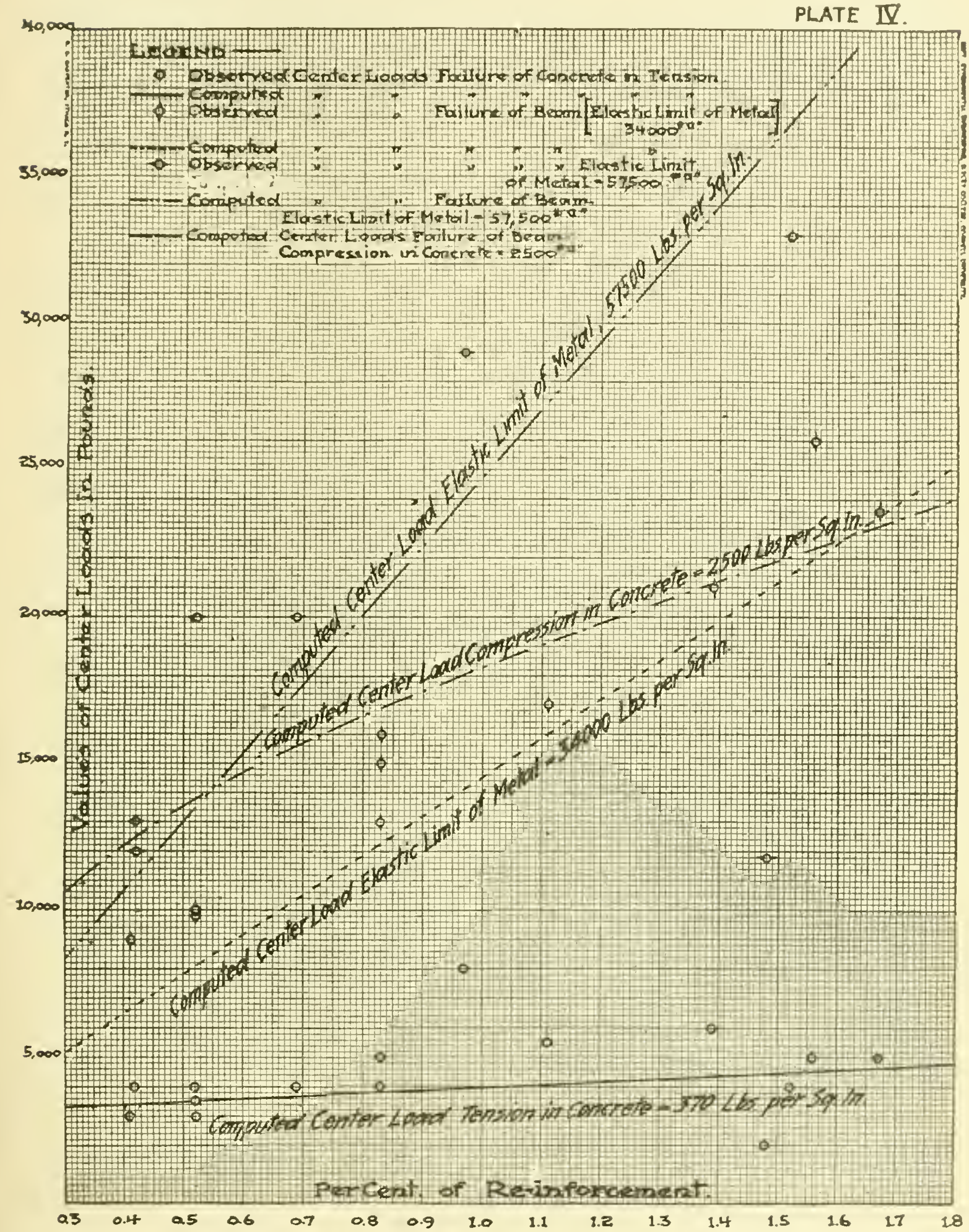
For the purpose of comparing the results obtained by use of the proposed formulæ with the results of tests, the center load at the point of apparent failure of the concrete in tension has been taken from the plotted results of Professor Talbot's tests of reinforced concrete beams.* In most cases this point could

---

* Bulletin No. 1, University of Illinois Engineering Experiment Station. Talbot, A. N.: Tests of Reinforced Concrete Beams.

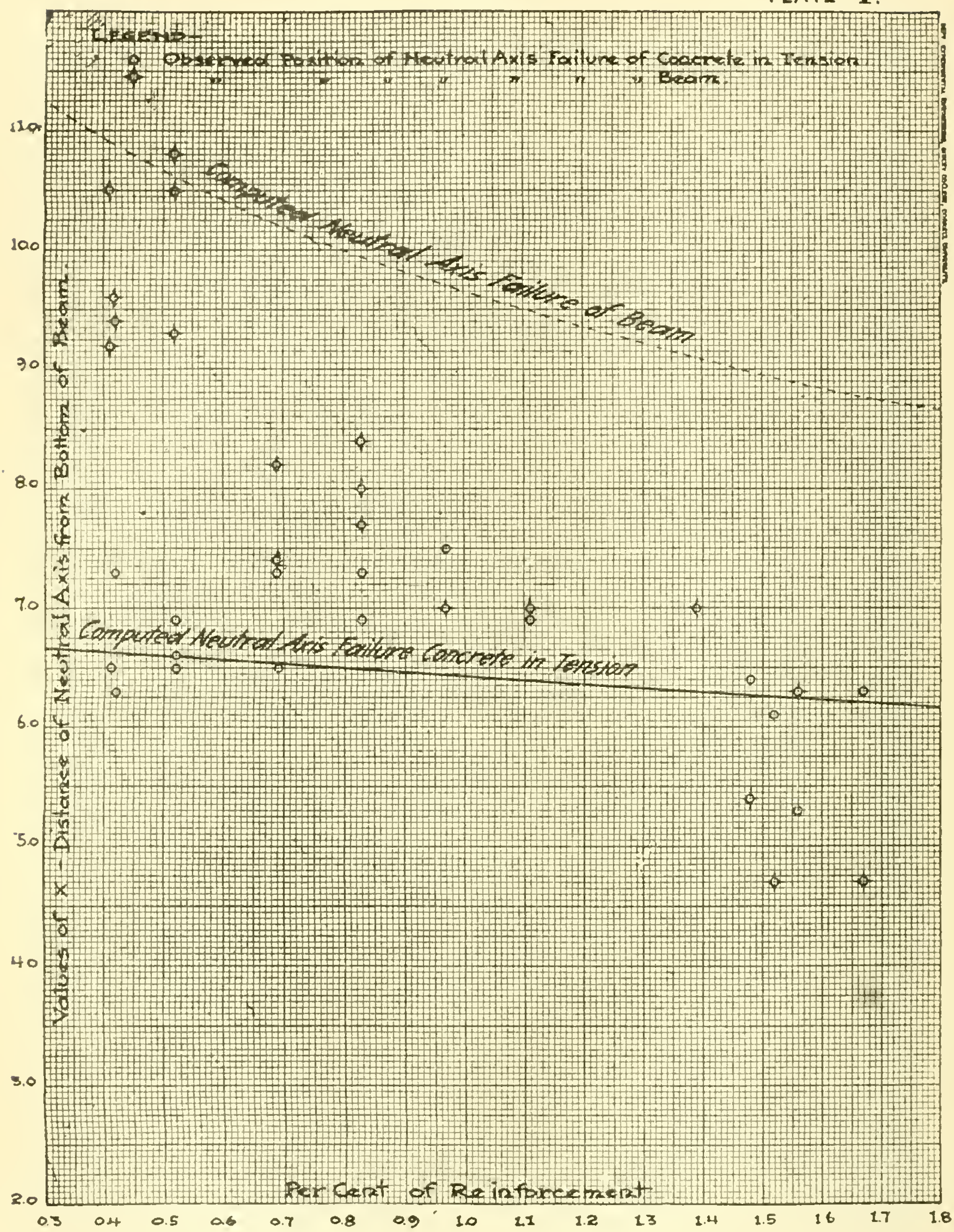
be determined from the published diagrams with sufficient accuracy for the purpose of the present comparison. The observed position of the neutral axis at this point as determined

PLATE IV.



by extensometer has also been recorded. Similar quantities have been computed by means of the proposed formula and the results tabulated in Table I and shown graphically on Plates IV and V.

PLATE V.



For this purpose the bending moment of the external forces in inch-pounds, including the weight of the beam, has been taken as

$$M = 28\,P + 49\,400,$$

M being the bending moment in inch-pounds and P the center load. Substituting this quantity in equation (12) there results

$$P = \frac{S_c b d^2}{28} \quad [\quad] \quad - 1\,764.$$

TABLE I.

No. of Beam.	Per Cent. and Kind of Reinforcement.	Apparent Center Load. Failure of Concrete in Tension.	Calculated Center Load. Tension in Concrete 370 Lb. per sq. in.	Apparent X	Calculated X	Apparent Center Load. Failure of Beam.	Calculated Center Load. Elastic Limit of Metal.	Calculated Center Load. Compression in Concrete, 2 500 Lb. per sq. in.	Apparent X Failure of Beam.	Calculated X Failure of Beam.
17	.52 P □	3500	3510	6.9	6.6	10000	8000	13800	10.8	10.6
21	.41 P o	3000	3440	6.5	6.6	9000	6600	12300	9.2	10.9
27	1.56 P □	5000	4460	5.3	6.2	26000	22000	22400	6.3	8.9
16	.52 P □	3000	3510	6.5	6.6	9800	8000	13800	10.5	10.7
19	.41 P o	3000	3440	6.5	6.6	9000	6600	12300	10.5	10.9
10	.83 T	4000	3800	7.3	6.5	15000	12300	16600	7.7	9.9
15	.83 T	5000	3800	6.9	6.5	16000	12300	16600	8.4	9.9
14	1.11 K	5500	4050	6.9	6.4	17000	15900	19100	7.0	9.5
4	1.39 K	6000	4300		6.3	21000	19900	21200	7.0	9.1
22	1.67 K	5000	4560	6.3	6.2	23600	23900	22800	4.7	8.8
5	.83 K	5000	3800	7.7	6.5	13000	11900	16600	8.0	9.9
29	1.48 J	2000	4380	6.4	6.3	11800	35900	21800	5.4	9.0
3	.42 J	4000	3440	7.3	6.6	12000	11200	12500	9.6	10.8
7	.42 J	4000	3440	6.3	6.6	13000	11200	12500	9.4	10.8
20	.69 J	4000	3670	6.5	6.5	20000	17000	15600	7.4	10.2
2	.69 J	8000	3670	7.3	6.5	20000	17000	15600	8.2	10.2
13	.97 J	8000	3810	7.5	6.4	29000	24200	18100	7.0	9.7
28	1.52 J	4000	4410	6.1	6.2	33000	36800	22000	4.7	8.9
9	.52 R	4000	3510	7.3	6.6	20000	13500	13800	9.3	10.6

As near as could be determined from a study of the tests of the plain concrete, the value of $n = 7.5$ for these tests is probably nearly correct. The tests of the plain concrete beams give $S_c = 370$ lb. per sq. in. as the average value of the modulus of rupture of the concrete as determined by the ordinary theory of flexure. Substituting these values in the above formula, the results given in Table I and on Plate IV have been obtained.

A study of these results shows that at the point of failure of the concrete in tension the computed results for center load and position of the neutral axis agree with the results of the experiments as closely as could be expected. The computed straight lines of Plates IV and V in each case fairly average the plotted field of the tests. The computed results for center load and neutral axis at the point of failure of the beam do not agree as well with the results of the tests. The computed results, however, are on the side of safety and have approximately the same variation for all percentages of reinforcement.

This lack of agreement is undoubtedly due to the fact that even at the point of rupture of the beam there is a portion of the concrete carrying tensile stresses.* These tensile stresses could be included in the formula, but from a practical standpoint merely lead to needless complication. This is especially true if the point of failure of the concrete in tension is conceded to be the real measure of the strength of reinforced concrete beams in the same sense as the elastic limit of metal is considered to be the real measure of the strength of metal beams.

Conclusion.

Many formulæ for the design of reinforced concrete beams have appeared in the technical literature of the past ten years.

They may be divided into two classes:

Those considering the tension in the concrete and those neglecting the tension in the concrete.

By substituting the notation of the present article the variation of those formulæ from the formulæ here proposed can be readily determined and in some cases will be found to be slight. Thus, the formulæ of M. Considère † would be the same if the total tension in the concrete had been taken by him as $\frac{1}{2} S_c bx$ instead of $S_c bx$ (Fig. 1).

---

* The formula proposed by Professor Merriman would correct this error to a certain extent.

† Considère, A.: Experimental Researches on Reinforced Concrete; translated by Moisseiff, L. S., New York, 1903.

The formulæ that consider the stress in the concrete to vary as the ordinates of a parabola instead of a straight line give in equation (12) coefficients of $\frac{5}{12}$ and $\frac{2}{3}$ instead of $\frac{4}{12}$ and $\frac{1}{2}$ in the terms within the brackets of the right-hand member of that equation.

It is worthy of note that the late Prof. J. B. Johnson was one of the first to propose a formula identical with equation (14).*

The formulæ here proposed do not, therefore, vary materially except in arrangement and notation from some that have been quite generally accepted.

The arrangement here given has been chosen because of its similarity to that in use in the discussion of homogeneous beams, and Plates I, II and III have been prepared to serve a purpose similar to that served by the tables of properties of I beams in manufacturers' hand books.

It is hoped that a thorough discussion of the subject at this time will lead to a simplification of the methods for designing reinforced concrete and a better understanding of the difficulties and dangers encountered by the use of improper methods.

NOTE. — DISCUSSION of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

---

* *Engineering News*, 1895, i, 10.

REINFORCED CONCRETE CONSTRUCTION: ITS PROPER APPLICATION IN EARTHQUAKE COUNTRIES.

By Charles Derleth, Jr.

[Read before the Technical Society of the Pacific Coast, December 7, 1906.]

Introduction.

Ever since April, 1906, the date of our earthquake and attendant fire in San Francisco and Santa Rosa, greater and renewed interest has been shown, the country over, regarding the merits of reinforced concrete construction, and in particular regarding its applicability in the design of city buildings. For some years interest in this type of construction has been rife, and since the San Francisco disaster the subject seems to have been stirred to the limit of discussion. Unfortunately, at the time of our earthquake and fire, there were in San Francisco no true reinforced concrete buildings. A discussion of the subject, therefore, in the light of earthquake and fire damage within the earthquake belt, is necessarily meager, and arguments in favor of reinforced concrete construction cannot be altogether convincing.

The little reinforced concrete construction which already existed in San Francisco prior to the fire was mainly found in floors and interior columns. It is well known that floors and interior columns, irrespective of the particular materials of which they are built, suffered very little, if any, from earthquake vibration. Such parts of building frames in general were not subjected to severe earthquake stress or destruction. Consequently it may be concluded that nothing very definite can be stated regarding the earthquake resistance of this type of construction. Comparison, of course, must be made to first-class fireproof steel frame buildings, and not to that type of construction locally known as class B and class C. Arguments that may be advanced must be limited mainly to fire damage and fire resistance.

There were some examples of reinforced concrete retaining walls within the burned district. These walls were of rather bold design. In their highest parts they were 35 ft., and were built with counterfort ribs spaced about 8 ft. center to center. They were not injured by the earthquake, and naturally not by the fire.

There were a number of reinforced concrete buildings within the Bay region of San Francisco which were not subjected to subsequent fire, and all evidence in these cases, though necessarily extremely restricted, is decidedly favorable to reinforced concrete as a type of construction to withstand earthquake motion for well-built structures not to exceed six stories in height.

The subject is broader, however, than the study of effects in the recent San Francisco disaster. Within the past few weeks we have heard of the failure of alleged reinforced concrete menbers, or the collapse of so-called reinforced concrete buildings, in different parts of the country. In all such cases the enemies of reinforced concrete construction at once find arguments to condemn this type of building. I believe that reinforced concrete construction for such buildings must not only be defended from its so-called friends, but at the same time its good qualities and its limits of adaptability must be explained and called to the attention of those who do not seek to be its advocates. The construction as a type must not be condemned by the citation of a particular failure, especially when the example given represents a most faulty case of design. Moreover, where the so-called friends of reinforced concrete have devoted this excellent combination of materials to a purpose for which the combination is not well suited, and under conditions of design which indicate a decided lack of knowledge and appreciation of the mechanical principles involved, then it is the duty of qualified engineers to call attention to the faults and weaknesses of the resulting structures. In all such cases, the attention of property owners and prospective builders should, wherever possible, be called to the specific inherent defects of design which have caused the failure, or, in general, which may, and often do, produce failure; and in such cases the engineering critic should take pains to emphasize that the collapse or destruction of whatever kind has been the result of bad designing, and that it is entirely independent of the particular kind of materials used, be they reinforced concrete on the one hand, or rolled steel shapes on the other.

Unfortunately, there are too many cases of inadequate design and improper methods of field construction for reinforced concrete, which are daily being forced upon the building public, and it is the duty of conservative engineers now to protect a meritorious class of construction at a time when its reputation is apt to be ruined by a host of incompetent persons who are claiming expertness in its use and application.

No sooner had the news been spread that the Bixby Hotel * at Long Beach, California, had collapsed, than it was at once proposed by one of the labor organizations of the state to appoint a commission for the purpose of investigating the disaster and placing the blame. It was promptly suggested by this organization that engineering talent be commissioned to examine the collapse and to inquire primarily whether the failure was due to the fact that the building was constructed of concrete and steel. It would appear that there are many interests ready and alert to find evidence against and to condemn the use of reinforced concrete, and I repeat, it is necessary at this time not merely to protect the material against some people who believe themselves its friends, but also against those interests which are naturally averse to its introduction.

Calculations.

The paper by Mr. C. B. Wing, presented this evening, and dealing with proposed formulas and tables for the practical calculation of reinforced concrete beams, leads me to say something regarding the great need at this time of greater uniformity in method of calculation, greater simplicity in the treatment of theoretical considerations and a lesser tendency to the use of specialized empirical formulas.

During the past few years much has been written regarding theories for the mechanical action of reinforced concrete beams and columns, and a host of authors have advanced as many different formulas. It would seem almost that no two engineers can agree even for the simplest calculations; as a result, the layman has been lead to believe that it is not possible to handle the design of reinforced concrete members with that degree of exactness and certitude which is assigned to the calculation of rolled steel members.

We should have greater uniformity in method for calculating the strength and proportioning the parts of such simple members as beams and columns. There is no reason why such members should not be designed and proportioned by applying the well-established principles of statics. There is no reason why we should insist upon a peculiar and more complex assumption for the variation of fiber stress in a concrete-steel beam than the

* For a description of the collapse and for other information relating to the design of the Bixby Hotel, consult: 1. *Engineering News*, Vol. lvi, page 555, November 29, 1906; 2. *The Architect and Engineer of California*, November, 1906, article by Mr. John B. Leonard.

simple straight-line law which satisfies us in the case of rolled steel. Special formulas bearing the names of so-called expert authors are unnecessary; in fact, they are misleading, confusing and pernicious. Fantastic theories which introduce a parabolic law of variation of fiber stress have absolutely no foundation in fact when we remember that we are dealing with working compressive stresses in the concrete, and not ultimate stresses, and when Hooke's law is assumed to hold at the same time; indeed, such laws for fiber stress variation have no especially practical merit and lead to no essentially different or more accurate results than would be obtained by the more rational straight-line law, and in general by more straightforward procedure.

Let us abandon special formulas, which we have not time to carefully examine, and whose practical limits of application are not given. Let us secure instead at least a more general appearance of agreement between designing engineers for the standard methods of calculation by being satisfied to apply to reinforced concrete designing the same fundamental principles of mechanics which all of us are now willing to use in the case of structural steel.

Volumes have been written on the design of reinforced concrete beams alone. Because there is no definite coefficient of elasticity for concrete, and no well-defined point which may be termed an elastic limit, certain ingenious authors have proposed a parabolic variation of fiber stress, at the same time assuming Hooke's law to hold and that plane sections before flexure remain plane afterward. Why not make the same assumptions for rolled steel beams? Steel is more ductile than concrete, and therefore has a greater range of ultimate values for the coefficient of elasticity. A great deal of scientific nonsense has been written because certain writers will insist on applying the properties of concrete, applicable near its ultimate resistance, to design formulas, which formulas should concern only working stresses, instead of adhering to figures commensurate with working stresses and not with ultimate values.

Why introduce into the design of reinforced concrete beams refinements of calculation which cannot be satisfied by practical construction? Why calculate the effective depth of a reinforced concrete beam to a hundredth of an inch, when we are lucky if the steel rods are placed in the field within half an inch of the position shown on the design drawing? Why make allowance for the effect of parabolic variation of fiber stress upon the resisting moment of compressive concrete, when such effect is within the

limits of accuracy of practical calculation? For the same reason, why consider the possible action of some of the concrete on the tensile side? The simpler we picture the stress behavior of a reinforced concrete beam, the better. The beam is the simplest of all members, yet we have succeeded in surrounding its design in reinforced concrete with an atmosphere of complexity and inconsistent refinements.

A reinforced beam, like a beam of any other material, consists essentially of three parts: 1. A compression flange; 2. A tension flange; 3. A web. The compression flange is of concrete; the tension flange of steel; the web is concrete properly reinforced by diagonal steel rods or stirrups.

I. The compression flange in customary design needs no steel; in buildings, especially floors, it is only necessary to determine where the compression flange is; that is, if building laws allow the designer to consider continuity, or, in the case of high buildings, if wind stresses may reverse the normal conditions for dead load.

II. The tension flange, in accordance with the preceding remarks, may properly neglect all of the concrete in the calculation for resisting bending moment; as in the case of the compression flange it is necessary to decide which is the tensile flange at any given section in any particular span of a structure. Prof. Mansfield Merriman has developed simple formulas (see *Transactions American Society of Civil Engineers*, Vol. lvi, p. 376) which take account of some tension in the concrete when considering bending resistance. These are most excellent formulas and are very simple. But why not neglect the tensile concrete since it is so near the neutral surface, and its stress intensity relatively so small that the resulting resisting moment thereof is properly neglected in practical calculations when compared to the resisting moment of the compressive concrete and the tensile steel?

Professor Merriman, in his article above referred to, aside from his discussion of economic proportions and economic working stresses in the steel, refers to a most important matter when he emphasizes the three fundamental equations upon which all elastic discussion must be based, and from which but three unknown quantities may be independently computed. From my experience, at least, it would appear that many practitioners fail to appreciate this fundamental matter and they often assume arbitrarily at least one more quantity than they have a right to assume, and thereby they introduce into their calculations considerable inconsistency.

Volumes have been written, starting with the researches of A. Considère, relating to the cracking of concrete on the tensile side of a reinforced beam. I have stated that in a simple treatment of beams we should neglect the effect of tensile concrete in the resisting moment. The metal reinforcement of the tensile flange, in other words, merely happens to be encased in concrete, some of which concrete forms an essential part of the web of the beam. That concrete cracks and everybody should know that it does. If the tension steel is subjected to possible corrosion or to probable weakening by the heat of a fire, then must that tension steel be protected — this is a problem of protection and can be solved.

All structural members of reinforced concrete which take computed stress, or which form essential parts of the building frame, in the opinion of the writer, must in rational design be protected by an envelope just as much and to the same extent as a structural rolled steel member doing a similar duty. Such an envelope must not take computed stresses; it must protect the main member from corrosion or fire, even though it, itself, be destroyed by heat or the action of the elements. Proper observance in design for the necessity of protecting envelopes to main reinforced concrete members would prohibit, in some instances at least, the use of reinforced concrete versus rolled steel. Its prohibition would be due to cost, or to largeness of cross section, or both. A case in point would be a main column in the lower stories of a high building constructed of reinforced concrete; such columns properly protected would often be of unsightly and prohibitory size and would cost more than equivalent built-steel columns.

III. The function of the web of a reinforced beam is to hold the two flanges apart and at the same time together in rigid unity of action so as to maintain under working loads safely and permanently the effective depth of the member. This web is of concrete, usually of rectangular cross section. We have already seen that it is apt to crack where it is found on the tension side of the neutral surface; such cracks are produced mainly by the tensile fiber stresses, in which consideration the action of the concrete is neglected. The web concrete, however, in addition, must withstand other important stresses which cannot be neglected. The web concrete must withstand at all sections of the beam the maximum intensity of transverse shear and the equal maximum intensity of longitudinal shear: it must also be able to take the maximum diagonal tension. All three of these

quantities are maxima at the neutral surface, and absolute maxima at the abutments.

The diagonal compression, of equal intensity at the neutral surface to the diagonal tension and approximately numerically equal to three halves of the average shear intensity at any given section, need not be considered in discussing the web strengths of beams. It will be found that beams otherwise properly proportioned can safely resist diagonal compression.

I have already insinuated, and it is thoroughly well known, that the intensities of the transverse and longitudinal shears and diagonal tension are equal at the neutral surface, each being approximately three halves of the average transverse external shear. To safely withstand these intensities, the web concrete near the abutments must usually be reinforced with metal. It is these web stresses which are most grossly misunderstood, improperly neglected or imperfectly provided for by our reinforced concrete experts. In fact, many of these experts probably know nothing, or have forgotten what they studied in college, about lines of principal stress in beams; and if this be true, they know very little, if anything, about those theorems of stress, principally the theorem of the ellipse of stress, upon which such analysis must be based.

It is not the purpose of the writer to consider every possible detail in this argument. Something may be said about T-beams. The principles of design for hooped columns have been well established. What we need in all these matters is uniformity and simplicity, avoidance of refinement not consistent with practical accuracy and calculations based upon sound mechanics, with an appreciation at all times of the degree of exactness of the working assumptions.

Frame Work and Calculations.

After all, the fault with reinforced concrete design is not in the application of theory so much as it is a practical matter relating to the treatment of details. Though different designers may employ different formulas and different kinds of patented bars, in the main, the resulting members, when designed by competent engineers, are entirely safe, where good workmanship and inspection are secured.

In reinforced concrete city buildings of the better type, the individual beams, floor slabs, columns, etc., are usually of intelligent and safe proportions. It is not to these component parts that criticisms can generally be applied. To be sure, in the re-

cently collapsed Bixby Hotel the columns were of inadequate design; but we cannot consider such a building as an example of good construction. It is not a building for present argument.

In the better types of buildings, in general, though their component parts are carefully designed and no criticism may be found to apply to their component beams, girders and columns, nevertheless, they are apt to be weak at joints, or, in other words, at important connections they are not properly provided with continuity of framework. Our more pretentious reinforced structures are often lacking in unified framework. There should be more regard given to continuity and stiffness of joints, as in steel frame buildings. No important part of the frame should be omitted. The columns should be continuous from floor to floor, and not be dowelled into floor slabs. There should be main floor girders, both transversely and longitudinally between columns, and there should be knee braces between these girders and the columns. None of these requirements was satisfied in the Bixby Hotel.

Again, there should be more attention paid to continuity in beams, girders and columns. In short, as in steel frame structures of the best type, the reinforced concrete building of any considerable height should and must have a well-unified, well-stiffened, rigid, yet elastic frame to which the curtain walls are attached, and upon which the floor slabs rest. Such a structure would have lateral stiffness and would be able to withstand transverse shock, wind vibration and possible earth tremors.

This argument does not imply that steel frames in general satisfy the conditions for unity of framework. There is great abuse and neglect of these principles in the ordinary steel frame construct on, and it is to be deplored that we do not find more open criticism in this regard for steel frame structures.

The writer considers reinforced concrete a most excellent material for low buildings, especially for buildings of two or three stories, where stiffness and solidity are desirable elements. Certainly a monumental effect can readily be obtained with this class of construction for theaters and hospitals, and for such buildings reinforced concrete should be especially adaptable where the height is limited to, say three stories, particularly when scientific design has been applied, where generous and safe proportions have been employed and where the best materials have been used, sound workmanship secured and inspection provided.

Tall Buildings.

But for tall, slender buildings of the skyscraper variety, say buildings over ten stories in height, the writer believes it a mistake to attempt the general use and application of reinforced concrete for the structural frame of the building. Not that a reinforced concrete edifice of small base and considerable height cannot be built safely and with a certainty of safety, but that this type of construction for towerlike skyscrapers is less worthy, or rather less adaptable than a structural steel frame clothed in properly reinforced concrete and sufficiently anchored masonry. Such masonry itself might be reinforced concrete, but the writer would just as readily advocate properly anchored reinforced brick work, high-grade terra-cotta, or cut stone. Popular taste and architectural decoration will very generally demand much use of brick, terra-cotta and stone for the curtain walls of buildings; and even in earthquake countries such material can be employed safely.

For very tall buildings in earthquake countries, we need a deep, substantial foundation, and a strong, elastic, well-knit, well-unified frame. For high buildings in San Francisco the foundation should be deep. This requirement with special emphasis should be demanded in the greater part of the business district, and particularly on the soft or made land. Where the base of a building is small compared to its height, it is my opinion that the foundation for soft-ground sites should be a unit of the slab variety; but for buildings of a broad base, individual piers are entirely right and proper, so long as they reach to considerable depth of foundation bed and insure essentially equal intensities of pressure and therefore practically equal settlement at all points in the foundation plan. The writer believes in and leans toward the use of wood piles with concrete grillage on permanently wetted sites. He would also advocate the use of structural steel; that is, rolled I-beams and channels as major reinforcements, so to speak, in deep foundation slabs of concrete, rather than the introduction as a substitute of thick slabs of concrete in which are imbedded only the ordinary plain or deformed bars of modern reinforced concrete practice.

Earthquake Stresses and Framework.

During the past six months, and especially in San Francisco engineering circles, much has been said concerning the calculation of so-called earthquake stresses in frames of structures. It is the writer's opinion that we cannot calculate the intensity of a so-called earthquake stress in a given member of a building

frame, because the earthquake forces are of indeterminate magnitude, and are brought into action to amounts directly proportionate to the degree of stiffness of a structure distorted by them. In other words, the elastic work produced by earthquake deflections, or the rupture work done by earthquake destruction, will be measured directly by the amount of resistance offered.

It has been advocated by some of our local San Francisco engineers that in tall buildings there should be a certain freedom of transverse bracing in the lower stories, so that such buildings might more readily take up, through the elasticity of their first story columns, shocks due to the motion of the ground. There is much of merit in this proposition, and our structural designers might with propriety give some study to the idea. Of course, it should not be argued that bracing should be entirely omitted from the first story; such procedure would put the building on stilts, a feature all too common in many steel frame designs of the past, a practice all too little condemned. In properly carrying out the idea of limberness in the first story, we should insure stiffness and continuity in the columns, and at the second floor framing level there should be special provision for the strength of connections between the floor girders and the main columns. In this way we should secure a well-framed box from roof to second floor level, a box resting upon and securely tied to freely vibrating vertical columns in the first story; and these columns in turn would be founded upon a deep and substantial foundation. Such a building would offer less resistance to distortion in being vibrated by an earth tremor, and the induced earthquake stresses would be so much the less harmful. The picture which I am trying to paint is a parallel to that in the fable of the oak-tree and the willow-tree. The willow tree bends to the fury of the storm, while the strong and stiff oak is cracked and rent.

You must notice that there is in this argument an idea entirely apart from the elasticity of the component materials. It is the idea of so designing the framework that it as a unit may yield in its elasticity, and prohibit the calling forth by its resistance of an unlimited force or energy from nature's storehouse.

This brings me to an important observation bearing, in my judgment, upon the use of structural steel versus reinforced concrete for the frames of tall buildings of relatively small base. Let us grant that both types of material in themselves have considerable elasticity. Let us grant also that provision can be made in the designing of framework for both to insure that yielding of structure which we have argued is desirable in buildings, especially in their first story columns; then that type of material

is most desirable for an earthquake country which can yield most. Unquestionably, in my mind, the high structural steel frame building can be made to satisfy the requirement most nearly in the present stages of the art of engineering science and of architectural art.

For lower structures, where solidity is required, structures from three to four stories in height, there is a lesser tendency to destructive vibration than in tall buildings. Here a reinforced concrete framed building, as one feasible solution of the problem, is heartily recommended because it can be built with integrity and rigidity of frame. Surely it would not crack to pieces and fall into a heap of rubbish as many buildings of the brick-wood combination did in San Francisco and vicinity last April. But the reinforced concrete building must not be assumed to be the only good solution for the solidly built structure of relatively low height. A structural steel frame, it must be observed, would do no harm even in a concrete theater or a concrete hospital.

In our important high structures we need, first and foremost, a solid foundation and a wiry, elastic, stiff-jointed frame; of second but no less great importance we require floors and enveloping walls of masonry properly reinforced and securely anchored to the skeleton frame of the building.

The skyscraper is still a new problem for the architectural designer. For such a structure must be developed a scheme of its own. A new architectural order, so to speak, must be created, an order of design which will be in harmony of expression with the engineering skeleton which gives the backbone of stability to the form. For tall buildings, reinforced concrete, in the judgment of the writer, will play an important part in future architectural and structural treatments, but we must be careful to observe that structural steel, especially for the building frame, demands at least equal consideration. A logical combination of rolled steel and reinforced concrete, it is believed, will affect the architectural treatment of skyscrapers in the immediate future, and will influence the architect's decorative treatment.

Architects must learn to appreciate that a heavy masonry envelope on a high framed building, in which much steel is employed, is bad engineering. They must be taught that in earthquake countries, at least, a heavy envelope of curtain walls, consisting of brittle, unreinforced, unanchored material, is especially bad engineering. Let us hope that such procedure may be considered also improper architecture.

[NOTE.—Discussion of this paper is invited to be received by Fred. Brooks, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

ENGINEERING WITHOUT SPECIFICATIONS.

By R. S. Colnon, Member of the Engineers' Club of St. Louis.

[Read before the Club December 19, 1906.]

When asked to respond to a toast this evening by a member of your committee, there was no accompanying blue print or a line of specification, so that I consider it a great privilege for a contractor to be allowed to address one or more engineers with no limitations whatsoever, and if what I have to say seems to be somewhat disconnected, and to cover rather a large field, you have your committee to blame.

First, I would ask the question, Why are engineers and their work not more highly appreciated by the community?

Certainly not because their work lacks commercial importance, for the members of this club probably have charge of and are directly responsible for the expenditure of more money than any like number of men in this city.

The only answer that occurs to me is the engineer's innate modesty.

Of course this should be corrected, but, unlike other artists, their managers and employers do not seem inclined to exploit their merits or abilities as is done for the other professions. For example, how much do you hear of the engineers of the Panama Canal? Rather, you are treated in the papers and magazines to a picture of a big steam shovel, with the President sitting at the end of the boom, labeled "These two will dig the canal." Some one says this is as it should be, and rather as the men who have gone quietly about their business of study and investigation and carefully planned all this work before a shovelful of dirt has been moved would have it. That would be all right if we were to consider only the reward of the engineer himself, for no one is apt to overestimate the satisfaction the engineer enjoys in the execution of any carefully considered plan, and perhaps this feeling is, at times, intensified by the fact that he alone sees and appreciates the value of his toilsome planning, and that he himself is lost sight of and left to his own selfish enjoyment.

But the harm comes later to the public and his employers when some great work is to be undertaken. The necessity for this study, investigation and toilsome planning is all forgotten and they want to see the dirt fly.

Because this work of the engineer was not thought necessary or duly appreciated by the public at large, we have just been given a fine example of how not to do it in the matter of a municipal bridge. An association of well-intentioned gentlemen, with the aid of the newspapers, without study, investigation, toilsome planning or consultation with the unimportant engineer, have presented estimates and plans (all except the location having been, I believe, determined on) to the voters of this city, which have been approved by said voters, and we are told by the great religious daily that what the public endorses is always right. It has, however, before now been determined that one thousand men can just as easily as one man reach a wrong conclusion if their information is wrong, or if, as in the above-mentioned case, they assume no information is necessary.

So I am back at the question, Who shall extol the virtues of the engineer? who exploit his achievements? and I can find none better than his own modest self.

I would have him act as his own manager. I should say that if a man has the necessary qualifications for chief engineer of the greatest canal the world has known he does not need a manager, but rather a chief clerk.

If a man is preëminent in the economical location and construction of a great railway, he ought to make a pretty fair stagger at operating same. Mr. A. M. Wellington, the man who has written most intelligently of the operation of railways, made his reputation locating and building them.

I would not have the engineer in his self-exploitation adopt the methods of the fakir; I would have him tell the truth, but tell it first. Don't always wait till some one comes for an opinion. I would have him take the initiative, be something of a promoter. De Lesseps was the promoter of the Suez canal, but was used by others in the Panama fiasco; in other words, he allowed himself to be promoted.

Don't set up the claim to your client that you are going to buy a thousand brick or a ton of coal cheaper than any one else and that your chief claim to his consideration is your ability to prevent his being robbed by his contractor; but rather on your ability to assemble in an intelligent plan material, machines and forces such as will give economy in output, and a fee for that kind of service, however large, is small in relation to its value in the final result.

While I admit having at times tried to do a little missionary work among engineers in behalf of the much maligned contractor,

I would suggest that the engineer in furthering the interests of his own business attempt a little missionary work among contractors to the end that the contractor come to see the wisdom of looking upon the interests of the engineer and his client as his interests; which relation, if it could be brought about, would help to relieve the engineer largely of police duties and would enable him to point out to his client the excellent service his contractor was giving him, rather than have all his time taken up watching the contractor, thereby convincing his client that he was being robbed and perhaps making him suspect his engineer of being a partner in the robbery.

Don't ever try to throw dust in the eyes of your client or hide behind scientific jargon; in other words, don't make explanations and claims to him in terms you know he does not understand, for if you have blundered he is bound to see the result in your work, and whenever he hears these terms repeated he shies, and his definition of an engineer is apt to become one using strange terms of a science which applied ends in disaster.

Engineers are too apt to play the part of Phocion, who, when sent on an important mission to the Macedonians, simply made his statement of the matter and refused to say more, but left the orators to wrangle over terms; yet Carlyle says he was as effective as Demosthenes. But Phocion was compelled to drink of the poisoned cup and Demosthenes was spared. To be sure, they erected a monument to him later.

I would say in conclusion that to-day in this republic the engineer should not forget that human nature is a part of nature, and while you may eliminate the error of personal equation in mathematical discussions, it is, nevertheless, a great error to try to eliminate the personal and the human in the embodiment in brick and mortar of any of their theorems. My apology for my attachment to the cause of the engineer is that of Sancho Panza when it was said of him: "Since Don Quixote is a fool and madman, yet Sancho, his squire, who knows it, follows him and relies on his vain promises, must be more mad and stupid than his master." Sancho says: "I know it's true, and had I been wise I should have left my master long ere now, but such was my lot and such my evil errantry, follow him I must; we are of the same town. I have eaten his bread; I love him; he returns my kindness; he gave me his ass colts and, above all, I am faithful."

[NOTE.— Discussion of this paper is invited to be received by Fred. Brooks, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

"FOURTEEN FEET THROUGH THE VALLEY."

By Harry B. Hawes.*

[Read before the Engineers' Club of St. Louis, December 19, 1906.]

"Fourteen Feet through the Valley" means a 14-ft. waterway from the Great Lakes to the Gulf.

It means increased facilities for transporting freight and the consequent saving of hundreds of millions of dollars to both producers and consumers.

It means a natural, God-made regulator of freight rates for the entire country.

It means the increased value of land and its products for the Mississippi Valley by securing new markets and more direct transportation at cheapened cost.

It means immediate facilities for trade with the Orient and South American republics, which will place the people of the Mississippi Valley on a competing basis with the Atlantic and Pacific seaboard states.

It means the reduction of the transportation tax which is paid by all our people.

It means that St. Louis will become the greatest inland city in the world.

The Valley.

Our portion of the valley spreads broadly between two mountain chains, rising gradually as we travel north less than 1 000 ft. in 1 000 miles.

With a temperate climate, it forms the most wonderful territory in the world; with natural resources unsurpassed, it is only beginning to develop by the arts of man.

A competent authority has, perhaps, summed up its physical perfections in saying that it can support from 400 000 000 to 500 000 000 people and carry on trade with as many more when it has reached the Old World density of population.

Water power is to-day the greatest of its undeveloped resources.

Through its center for a distance of 3 160 miles flows the Mississippi River, whose great eastern tributary, the Ohio,

* Chairman of the Speakers' Committee of the Lakes to the Gulf Deep Waterway Association.

reaches a distance of 975 miles to the Alleghanies, and the Missouri extends west to the Rockies a distance of 2 575 miles.

It would test your patience and confuse you to name all the navigable rivers emptying into the great trunk stream; it will suffice to say that in the valley 15 000 miles of navigable streams exist.

Each navigable stream means a transportation highway; each new highway will help just so much to remove freight congestion and lower the cost of its moving.

Freight Congestion.

Mr. James J. Hill, the railroad expert, has said that in the last ten years the growth in ton mileage was 110 per cent., whereas the growth of railroad mileage in the same period to handle the traffic was only 20 per cent. Continuing he said:

"The traffic of the country is congested beyond imagination. The commerce of the country is paralyzed, and continued, it means slow death.

"More cars? Yes, we need more cars, but we need also cars of greater capacity, heavier trains and more miles of railroad to haul them over. In ten years the railroads of the country expanded 20 per cent. for the handling of a business that increased 110 per cent. Suppose you are able in the near future to increase that expansion 50 per cent? That will still leave 40 per cent. a year of the business without any facilities for taking care of it.

"It is estimated that from 115 000 to 120 000 miles of track must be built at once to take care of this immense business. But to build that amount will cost as much as the Civil War cost, at least. It will cost from $4 000 000 000 to $5 000 000 000. A thousand millions of dollars a year for five years will scarcely suffice. Why, there is not money enough nor rails enough in all the world to do this thing!

"And if the rails were piled up ready for the undertaking, and if the money were in bank to-day, it would be impossible to get the labor with which to do it.

"I tell you, there is no question since the Civil War of half the consequence of this one. Why, you can't go out and contract with any railroad in this country to move 500 cars of freight from here to New York in thirty days. And the railroad could not deliver if it should contract to do it.

"The great cry is that there are not cars enough. The trouble is that you can't put cars on the track and get half the movement out of them that you could ten years ago. Statistics show that freight cars running from 12 to 15 miles an hour average a movement of 25 miles in 24 hours. Think of it — only 2 hours a day in operation! Is there any business in the world that can sustain itself when its equipment is in use only one twelfth of the time?"

Such facts and figures coming from such well-accepted authority astound us.

This congestion, which paralyzes trade and affects the pockets of all, can be removed by a proper regulation of our waterways.

We have in the Mississippi Valley 15 000 miles of natural waterways requiring regulation alone to become serviceable for this purpose.

Who Is Responsible?

The natural questions, then, are, Why have they not been regulated? and, Who is primarily responsible for such apparent, almost criminal, neglect?

First, there has been a lack of intelligent, persistent and systematic effort upon the part of business men in educating the people to the possibilities and benefits of this work.

Second, the transportation question has not been, until recently, understood to affect every man alike in all walks of life; the average citizen did not know that he paid a transportation tax and that he had some voice in the regulation of rates and in stopping discriminating rebates.

Third, Congress, which is ready and willing to follow an enlightened public sentiment in favor of any great public enterprise, has refused to make adequate appropriations necessary for this purpose in the absence of clearly expressed public sentiment favoring it.

This leads us finally to place the blame where it properly belongs, not upon the national government, but upon our people for not making a determined demand, backed by a compelling public sentiment favoring necessary appropriations for river regulation.

At present there is no party politics in the demand for an adequate appropriation; there should not even be a sectional question raised; for, while the Mississippi Valley will make the demand, second thought will lead the whole nation to believe that it is a national, not a sectional, issue.

While we know that the question is national, and will avoid a sectional issue if possible, yet, if it must come, certainly we feel assured that a properly expressed demand made upon Congress by our representatives from the Mississippi Valley will not fail.

After public sentiment is aroused, and an intelligent plan proposed, we will soon learn to pick our friends from our opponents; we can then both reward and punish without injustice.

A Special Plan.

It is not enough that a general plan of deep waterways and the improvement and regulation of navigable streams should be advocated, but some special, exact and detailed plan must be presented first to the people and then to Congress.

Acting on this theory, an organization was formed in St. Louis last month having for its object a specific plan, a 14-ft. channel from Lake Michigan through the Mississippi River to the Gulf. This is intended only as a trunk waterway and is in no sense of the word antagonistic, but, on the contrary, upon completion, will be the strongest argument in favor of the regulation of all the tributaries of the Mississippi. Just as it would be unwise to attempt to build artificial waterway tributaries first and the trunk last, or attempt to build tributaries of a railroad first and the trunk line last, so it would be the height of folly not to concentrate, at least for the time being, on the trunk waterway. Our engineers, as well as Congress, must have some definite plan. We now have that definite plan, and it will be but a short time before all of its advantages will become known.

The Divide Removed.

Scientists tell us that at one time the opening of the Great Lakes was to the south, and that Lake Michigan spilled its surplus water into the Mississippi River. Nature, for some cause, changed the course of this outlet so that this water now flows through the Niagara.

When Joliet, in 1673, reached the Chicago divide from the lake side, he was shown by his Indian guide how to portage and take the river route to the great sea. He probably was the first white man to suggest the lakes to the Gulf waterway.

When Nature changed the outlet of the Great Lakes, she added greatly to the picturesqueness of our country by the creation of Niagara Falls, but she closed the old channel by a rock obstruction only 30 ft. higher than the present outlet. The city of Chicago, at a cost of $50 000 000, has again opened the old channel by cutting away the divide and letting the water of the lakes flow into the Illinois and thence to the Mississippi; so that a number of pleasure parties have started from Gulf ports, skirted the Gulf shore, rounded Florida, followed the coast line of the Atlantic, passed through the Great Lakes, down the Illinois to the Mississippi and stopped to visit us at St. Louis on their way to New Orleans.

Chicago now proposes to give its ship canal, which it secured at a cost of $50 000 000, to the national government, provided the government will complete the work from Lockport to the Mississippi. The present Congress will be asked for an appropriation of $3 000 000 to complete the channel from Lockport to Joliet, and the estimate of the remaining cost of a 14-ft. ship canal from Chicago to St. Louis is $32 000 000.

It is believed that the work can be completed in ten years, and be finished before the completion of the Panama Canal.

Not a New Project.

This is not a new project. In 1808 Albert Gallatin, then Secretary of the Treasury, in a report to Congress, advocated the construction of a ship canal across the divide along exactly the same line as that adopted by the city of Chicago. It has been overshadowed, however, by questions seemingly of more immediate concern. Conditions have changed, and to-day the paramount question before the American people is undoubtedly that of transportation. The leaders of both political parties are demanding that something be done. The intelligent thought of the nation is directed to a solution of this question, and, naturally enough, water transportation is, for the first time, receiving that consideration which its importance justifies.

In Europe.

An examination of the subject has taken some of our experts to Europe, where they find that Holland, Belgium, France and Germany have a waterway development of 18 920 miles in a land area of 449 000 sq. miles, or 1 mile of waterway for each 23.2 sq. miles of territory. France has about 1 mile to 26 sq. miles, and Germany 1 to 29 and still expanding, while Holland and Belgium together have 1 mile of waterway to each 6 miles of territory.

We find the Mississippi Valley has 1 725 000 sq. miles and 15 000 miles of natural waterways capable of being expanded as development requires to 25 000 miles, all at the present time neglected by the government, of practically little use to our people and the cause of millions of dollars of damages to our Southern planters by reason of overflows and floods.

In 1896, Mr. Burton, chairman of the House Committee on Rivers and Harbors, said the United States had expended, since the formation of the government, for rivers, harbors and waterways of every description, a little over $273 000 000, while

France had, in eighty years, expended for the same purposes $706 000 000. And yet a single state of this Union has a larger area than all France.

France has nearly 2 500 miles of waterway and 3 000 miles of canals. Germany has 10 000 miles of navigable waterways, with about 3 000 miles of canals. The British Isles have 8 000 miles of canals, four of these alone costing $377 000 000. Even Ireland has 16 waterways, covering a distance of 749 miles.

Why All Valley Streams Meet near St. Louis.

Mr. Cooley, in discussing our proposed waterway, calls attention to a significant feature of the Valley of especial interest to St. Louis:

> "In the extension of low levels well north in the geographical heart of latitude 42 degrees, between meridians 87 and 92, Illinois is the lowest state north of the Gulf margin, having an average altitude of only 632 ft. above sea level, being 100 ft. lower than Indiana, 300 ft. lower than Michigan, 450 ft. lower than Wisconsin, 500 ft. lower than Iowa and 200 ft. lower than Missouri; lower even than Arkansas, Kentucky and Tennessee. This might have been inferred, for all the waters gravitate to her shores. The Missouri, the upper Mississippi, the Wabash, the Ohio, the Cumberland and the Tennessee, and all the water routes from the north land and the Great Lakes touch her borders. Such a condition carries a mild climate well north, and makes possible navigation in ordinary winters up to latitude 40 degrees at Chicago and Clinton."

Railroads Not Hostile.

It has usually been supposed, and may probably be true, that the great influence which railroads have unfortunately exerted upon our national law-making body has been hostile to large appropriations for the river. The expressions now given by leading railroad men exhibit a more liberal view, and we find no apparent hostility. This is due to the fact that railroad service, as at present constituted, is totally incapable of promptly moving our great crops and heavy freight at certain seasons of the year, resulting in a congestion entailing enormous loss to the farmer as well as to the manufacturer and consumer. It is interestingly said that,

> "Some 35 per cent. of the freight moved by the railways of the United States, bituminous coal and other minerals, are worth less than $1 per ton where produced; 17 per cent., anthracite coal, coke, iron ore and other products, are worth less than $2; and still another 12 per cent., coarse manufactures

like brick, cement and lime and wood, logs, etc., are worth less than $5 per ton. The consumer has only to consult his purchase price to know that railway transportation is by far the largest element in the cost of more than half the commodities that seek a market."

It will be freight of this kind that will be largely handled by water transportation. The railroads will have their monopoly of fast transportation, the connection between waterways and the haul to the waterways. They will, therefore, probably be content with this share of the business, especially as it will carry with it the transportation of all perishable goods and passengers.

Remembering what Mr. Hill has said, there seems to be no great reason why railroad influences at Washington should be antagonistic.

Railroad Regulation.

It is true, though, that river regulation will mean rate regulation and the competition will hurt.

Mr. M. C. Markham, traffic expert, showing the influence of the Mississippi River on railroad rates, said:

" The river, as can be readily understood, makes the rate from St. Louis to New Orleans. The railroads running between those points, to get a share of the traffic, must necessarily offer rates approximating those of the river craft. Chicago is not situated upon the river, but it would be put to a disadvantage as regards the Memphis or New Orleans trade if it were not put upon a relatively fair rate plane with St. Louis.

" By way of illustration: When the rate on wheat from St. Louis to New Orleans by river was 30.6 cents per bush., it was 70.2 cents per bush. by rail from St. Louis to New York. In thirty-five years the river rate fell from 30.6 cents to 4.25 cents per bush. to New Orleans, and the rate by rail to New York followed it down from 70.2 cents to 11.6 cents."

It is scarcely necessary to give illustrations of this kind. Competition means reduction in price in transportation as well as in trade.

The average cost of carrying a ton of freight, in 1904, by rail was 7.8 mills per mile. This was the average, but on the Illinois Central, which parallels in many places the Mississippi River, the rate was 6 mills per ton per mile.

The cost of transporting freight on the Ohio River was 0.76 mills per ton per mile.

The cost of transporting freight from Cairo to New Orleans was 6 to 7 mills per ton per mile, and the cost of transporting

freight through the Sault Ste. Marie canal in 1905 was 0.85 mills per ton per mile.

The cost, therefore, on three great waterways was considerably less than 1 mill per ton per mile, as compared with 7.8 mills per ton per mile on the railroads, making the relative cost of transportation by rail and by water 6 to 1 in favor of water transportation.

These scattering illustrations of the difference in cost between water and rail transportation, even coming as they do from high authority, are not entirely satisfactory. But they furnish the indisputable proof of the cheapness of water transportation as compared with that by rail.

The Government's Duty.

Early in the country's history the government assumed ownership and control over our navigable waters, and to-day it is the sovereign controlling power of all navigable waters. Having assumed this power, it is the duty of the government to exercise it vigorously for the benefit of all the people. It cannot escape responsibility for, or dispossess itself of, the slightest control over any navigable water without express permission of Congress, which that body has in the past very properly refused.

A delegation of St. Louisans appeared before the chairman of the Rivers and Harbors Committee and asked for an annual appropriation of $50 000 000. Mr. Burton seemed to think that a large amount. Mr. Edward Goltra, of this city, said to him that if the national government would give him permission to regulate the river and charge toll for tonnage, he would agree to bond the enterprise for $50 000 000 within thirty days. While this statement was probably made in an argumentative way, there is, to my mind, hardly any doubt that private capital would gladly invest and find it a money-making enterprise. If it would be a good investment for private capital, why would it not be equally good for the government?

The policy of the government has been extremely shortsighted and parsimonious. While spending 63 per cent. of its total revenue for war and preparations for war, it has only expended 3.5 per cent. of its total revenues for all of its lakes, rivers and harbors.

In Case of War.

With the intention of appealing to the warlike spirit which seems to possess some of our newspapers, the novel argument

in favor of the deep waterway has been advanced that it can be used in case of war with Great Britain. By a treaty between the United States and Great Britain, no warships are permitted upon the Great Lakes. After completion of this treaty, however, Great Britain built a deep canal through her territory, connecting it with the Lakes; so that, in case of war, she could send her fighting ships into the Great Lakes with expedition and place our lake cities in jeopardy.

It is contended that we can send all of our smaller vessels through the proposed channel, and then, by removing some of the armor and heavier guns from the larger vessels, they, too, could be sent from the Gulf to the Great Lakes.

Arguments in favor of our ship canal have been based upon questions of transportation and new markets. Its use, however, in time of war probably should not be underestimated.

Engineers of Ability.

The construction and engineering work of the proposed waterway are not matters that a lawyer ought to attempt to discuss before a society of engineers. I know that we have engineers of high ability, perfectly capable of planning and executing this great work, and that its success will depend entirely upon the amount of money placed at their disposal.

Nature has determined the route and furnishes the water. The control of the water and the regulation of the route are matters exclusively within the province of engineers. It is agreed that it is a mistake to make small appropriations at long intervals, as the Mississippi is a mighty, restless power and washes away each year many thousands of dollars of incomplete and partially finished work, losing millions of dollars to the government by its lack of continuous application.

The Ransdell plan calls for a regular appropriation of not less than $50 000 000 for all harbors and rivers of the nation, which it is proposed to continue for ten years, making a total sum of $500 000 000 distributed over a period of ten years. This will be sufficient to complete not only a 14-ft. channel from Chicago to the Gulf, but will amply provide for the Missouri, Ohio and other tributary streams, as well as all other rivers and harbors.

Can Be Built in Ten Years or Less.

The main unfavorable argument is the length of time required to complete the work of construction; a vague impres-

sion exists that it will be of great benefit to the next generation, but cannot be completed in ours. This is not correct. The channel can be built in less than ten years. As soon as it is known that the government has entered upon a systematic plan, we shall find that private capital will make investments in river craft and increased river transportation will begin.

Other Theories.

There is a theory for the control of the headwaters of the Missouri by the erection of dams to hold the water at certain periods of the year and regulate its flow at others.

Another suggestion comes from the southern states for the building of canals which will take off the surplus water, serving as drainage ditches and for irrigating purposes in Texas. These and many other interesting issues will grow out of the creation of the main channel, but the few minutes I have at my disposal prevent a discussion of them.

The possibilities are so great that they naturally grasp the mind of every intelligent man who gives them consideration.

One Result.

It would be a pleasure to picture the wharves of St. Louis crowded with foreign vessels, the river filled with craft taking away our products and bringing back the things we need from other climes, to draw upon our imagination and picture St. Louis, the great inland city of the world, midway between Chicago and New Orleans, close to the mouths of the great eastern and western branches of the Mississippi, in the center of the continent, surmounted by all the blessings of nature, the business heart of the nation.

How We Can Help.

This would be a pleasant task, but the practical thing is for all of us, through our clubs and associations, to discuss and advocate the passage by Congress of suitable appropriations, to demand of our immediate representatives an earnest cooperation in this work and to secure, by correspondence, the assistance of friends.

Let us give our commendation to those congressmen and senators who assist our project and oppose the reëlection of those who do not. The ear of a congressman is acutely sensitive to the demands of his constituents. It is our duty to arouse the constituents of all our representatives in the Valley.

If this is done, it will be an easy task for them to say to the congressmen of the eastern seacoast and those of the Pacific: We want our share of the national moneys spent in the Mississippi Valley. We are in favor of improving your harbors and rivers, but we want a fair share of the nation's money spent in that portion of the country where most of the nation's support comes from.

This is not yet a partisan question. Let us strive to keep it from becoming one. Some men, by natural inclination, find difficulties in the way of all progress and magnify them. It should be the especial duty of the Engineers' Club to solve these difficulties.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

Henry Clark.

Member of Engineers' Society of Western New York.

Henry Clark, son of Elisha and Elizabeth (Bristol) Clark, was born in Buffalo, September 8, 1839. Died July 3, 1905.

In early life he attended public schools until about fifteen years of age.

After learning the carpenter and joiner trade he advanced himself from a foreman to the head of the building department on the Western Division of the New York Central & Hudson River Railroad. He was a prominent member of the old Volunteer Fire Department for many years, being identified with the organization known as "Truck 2."

On March 11, 1863, he was appointed second lieutenant of Company D, 6th U. S. Infantry of the Corps d'Afrique, and was assigned to Ullman's Brigade, and served with the same at Baton Rouge, Brashear City and Port Hudson until August 17, 1863, when he resigned on account of illness and a gunshot wound.

He built and operated for about four years a logging and lumber railroad between Bay City and Tawas, Mich. He erected a large number of bridges for the Niagara Bridge Works of Buffalo, N. Y., and was shop superintendent for the same for about three years.

During the last fifteen years of his life he carried out a considerable amount of contract work in the way of buildings and bridges for railroads and a variety of work for the city of Buffalo.

He was a man of strong character, a born leader, possessed the faculty of organizing and controlling men, and was full of ready resources in the face of difficulties. He was a steadfast friend, a kind husband and brother. A widow and three sisters survive him.

William R. Haven.

MEMBER OF ENGINEERS' SOCIETY OF WESTERN NEW YORK.

WILLIAM ROSCOE HAVEN was born March 9, 1840, in Coudersport, Pa., only son of Samuel and Ann (Churchill) Haven.

He attended common schools at home until 1857, excepting one year spent at the home of his grandfather in Portsmouth, N. H., where he studied "navigation and surveying" and so learned how to find his position in the middle of an ocean or of a boundless prairie and thence to run a true course. This was the only technical schooling he had.

He began his work in civil engineering and surveying on a railroad in Wisconsin in 1857. The panics of 1857 stopped all railroad construction in the West, and he went home to Coudersport, where he was engaged in land surveying and other similar work until 1861. During this time he acted in the capacity of a "surveyor of timber," which is a business at present almost unknown; but at that time there was a large amount of pine land in the forests of Pennsylvania, and capitalists wishing to invest money in them sent men of good judgment into the forests to survey and estimate the amount of feet board measure of pine timber on certain tracts of land, often thousands of acres; and the fact that young Haven, scarcely twenty-one years of age, was appointed a "surveyor of timber" shows that even at that time he was possessed of such good judgment that capitalists reposed confidence in him.

From 1861 until 1880 Mr. Haven was employed almost constantly as a civil engineer in charge of the location and construction of railroads in the eastern as well as western states, filling positions in the engineering departments from rodman to assistant chief engineer, and in the operating department he was for a term of years division engineer and roadmaster of the Chicago, Burlington & Quincy Railroad.

As an engineer he was studious, painstaking, scientific and accurate, fertile in expedients, loyal to his employers and just towards contractors and workmen.

In 1880 Mr. Haven had increased from a rather slim youth to a size and weight that made it unpleasant for him to do the field work of a civil engineer; and he came to Buffalo and began work, that continued to the end of his days, as contractor for large works, beginning with Craigie, Rafferty & Yoemans, who had extensive contracts on the Erie and Buffalo Creek railroads, as their superintendent of construction; then in

partnership with his cousin William Haven, of Iowa, under the firm name of W. R. & W. Haven. They laid tracks in and around Buffalo for the D., L. & W. R. R.; they also built the United States Public Building in Syracuse and the shops and other terminals of the West Shore Railroad in Buffalo. In a few years William Haven withdrew from the partnership and "Rock" continued the business simply as W. R. Haven. Amongst the works constructed by him are the shops of the Wagner Palace Car Company, the shops and roundhouse of the Lehigh Valley Railway, as well as a part of the main line of this railroad, the buildings of the New York Central Railroad at Depew, and most of the buildings of the smelter works of the Calumet & Hecla Company at Black Rock.

In the later years of his life there was sharp, sometimes unscrupulous, competition amongst contractors, and "Rock" Haven was not a low bidder, but sought to get a fair price for first-class work. It has often been said of him: "'Rock' Haven understands only to do good work, and his directions were imperative to his sub-contractors as well as laborers to do good work regardless of cost"; and as a contractor he exhibited the same persistent qualities and good judgment that characterized him as a civil engineer. Such qualities corresponded to his large physical body, which was but a storehouse for the wealth and good cheer which he dispensed so freely to all his acquaintances. "Big hearted, happy man that he was, the memory of him will long linger with those who knew him."

He was a great reader and kept well informed on events old and new; his memory was such that he always remembered a face and could call a person by the right name even if they had not met for forty or more years.

He was opposed to shams of all kinds, not only of materials and constructions, but of men and women.

He had hosts of acquaintances wherever he lived, and he also had some friends.

He never found a church which seemed to be of help to him in solving the problem of his existence, and September 5, 1905, he passed on to that state where he could continue to try to solve this problem unhindered by material weights and beliefs.

In 1862 he married Narissa Wood. His wife passed away December 30, 1903; they had no children. His father, born in 1815, now lives in Coudersport, and three married sisters survive him.

He joined the Engineers' Society of Western New York, April 7, 1902.

Wallace Clyde Johnson.

Charter Member and Past President of Engineers' Society of Western New York.

Wallace Clyde Johnson, civil engineer, died at his home in Niagara Falls, N. Y., December 15, 1906, after a brief illness.

Mr. Johnson was a son of James W. and Frances Ann Johnson and was born in Granville, Mass., May 21, 1859. His education was received in the public schools of his native town, in Williams College and the Worcester Polytechnic Institute, and he was graduated from the latter in 1884 with the degree of B. S. In 1894 Williams College conferred the degree of M. A. upon Mr. Johnson, at the same time conferring special degrees upon Theodore Roosevelt and Joseph H. Choate.

For the first two years after his graduation from the Worcester Polytechnic Institute Mr. Johnson was employed as assistant engineer in the hydraulic department of the Holyoke Water Power Company, at Holyoke, Mass., where he began his professional career as an hydraulic engineer.

In 1886 Mr. Johnson accepted the position of chief engineer of the Niagara Falls Hydraulic Power and Manufacturing Company, which position he held until 1900, when he became consulting engineer for the same company.

In 1893 Mr. Johnson married Eloise Gertrude Murlless in Holyoke, Mass., and from that time they made Niagara Falls their home.

While chief engineer of the Niagara Falls Hydraulic Power and Manufacturing Company, Mr. Johnson designed and installed the first and second enlargements of that company's great hydro-electric plant, which was the pioneer plant to use turbine wheels under a head of over 200 ft., and the work was accomplished with such credit that he was called in consultation by many companies having power development or transmission problems to solve.

His consulting practice grew rapidly and to such large proportions that he maintained offices in Niagara Falls, New York City and Montreal, and he gave it his closest attention until the time of his death.

Among the many positions filled by Mr. Johnson the following are the principal ones: Chief and consulting engineer of the Niagara Falls Hydraulic Power and Manufacturing Company; chief and consulting engineer of the Shawinigan Water and

Power Company; chief and consulting engineer of the Bodwell Water Power Company, Oldtown, Me.; chief engineer of the Hannawa Falls Power Company and the Empire State Power Company; chief engineer, vice-president and general manager of the Albion Power Company; chief engineer for the reconstruction of the plant of the Chicoutimi Pulp Company; and consulting engineer for the Pittsburg Reduction Company and the Buxton Power Company.

In addition to the above-named works, Mr. Johnson has been consulted, or made examinations and reports, on numerous power projects in the United States, Canada and Nicaragua.

Besides this hydraulic work Mr. Johnson, prior to 1895, designed and superintended the construction of a system of sewers for Niagara Falls, laid out most of the new part of the city, had charge of the construction of all the electric railroads in the city, built a mill using 2 500 h.p. of water under 125 head for the Clifft Paper Company of Niagara Falls, laid out the electric railroad from Niagara Falls to Buffalo and had charge of many other smaller works.

When the state of New York instituted the State River Improvement Commission in 1904, the Governor appointed Mr. Johnson its first engineer commissioner, and when, in 1906, this commission was superseded by the State Water Supply Commission, he was retained as a member of the latter board.

At the time of his death Wallace C. Johnson was consulting engineer for four of the power companies for whom he had designed and constructed plants, and was engineer and general manager of the Albion Power Company.

Mr. Johnson was a member of the following societies and clubs: American Society of Civil Engineers, American Society of Mechanical Engineers, Canadian Society of Civil Engineers, the Engineers' Society of Western New York, American Institute of Electrical Engineers, Society of Arts, London; Niagara Frontier Historical Society, the University Club of Buffalo, the St. James Club of Montreal, and the Tarratine Club of Bangor, Me.

Wallace C. Johnson was a genial and kindly gentleman who drew to himself a host of warm friends, by whom he will be greatly missed. He was a tireless worker in his chosen profession, to which he was thoroughly devoted.

He is survived by his widow, his father and mother and one sister.

WALTER McCULLOH, *Committee.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVIII. MARCH, 1907. No. 3.

THE STRUGGLE FOR WATER IN THE GREAT CITIES OF THE UNITED STATES.

By MARSDEN MANSON, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society January 4, 1907.]

THE objects of this paper are to present certain features of the great problems of municipal water supply. It is not proposed to take up, except historically, the purely structural features, as these are fully treated in technical works.

The problems to be considered are those of ownership and those requiring a change of source or expensive treatment to render an impure water suitable for use in the home. The studies incident to these changes in ownership and source involve problems in economics and civic policy which are sometimes more difficult than those concerning the development, conduction and distribution of the supply. These struggles for ownership are fought out on two lines: (1) to hold, when once in municipal control; and (2) to gain or regain when in adverse ownership. They are gradually being won by municipalities, for municipal ownership has been and is yet gaining ground. It prevails in all the cities in the United States above the 21st class except San Francisco and New Orleans, which rank 9th and 12th, respectively.

Of the fifty largest cities in the United States municipal ownership obtains in all except nine (9), as follows:

San Francisco (9th); New Orleans (12th); Indianapolis (21st); Denver (25th); New Haven (31st); Paterson (32d); Omaha (35th); Memphis (37th); and Scranton (38th).

To present the history of any considerable number of these is beyond the limits of this paper; hence a typical case of each system of ownership has been selected and the principal efforts as to ownership will be outlined.

The two cities chosen for this purpose are *New York*, owning and operating its own supply, despite strong and repeated attempts to wrest it from the municipality; and *San Francisco*, in which the privilege of water supply is yet held by a corporation, despite more than a third of a century of effort to secure municipal control. Each of these cities is the largest of its type, and a study of their struggles for the ownership of this great necessity of life and health is full of instructive lessons, not only to the civil engineer, but to all citizens.

These two types stand opposed to one another, not only in the matter of ownership, but in the objects to be attained by such ownership. Under corporation control the prime object is *profit* — what can the investment be made to yield in dividends, salaries and interest? How can the stock be doubled or trebled with the least investment of actual capital, and how can laws restricting profits to a reasonable return on this actual investment be overreached?

Under municipal ownership the prime question is, What are the lowest rates commensurate with an abundant and pure supply?

Both systems have their drawbacks and advantages. Under corporation control there is frequently the advantage of long service, high skill and no politics, so far as officers and employees are concerned, but there is a standing abuse in the corruption of those officials charged with fixing rates,* and the consequent introduction and support of " the boss " in municipal politics, with all the resultant evils.

Under municipal ownership political control too often becomes the leading motive, so as to use the officers and employees as a voting power and these positions as political rewards. Hence the control and operation shifts with victory at the polls to the detriment of the public health and to the safety of property.

---

* So much has this obtained in San Francisco that a supervisor, after two terms as chairman of the Water Committee, took a tour around the world. Upon his return a shrewd Irishman, who knew the facts, remarked of him, " That is the shmartist man Oi know. He wint entoirly around the worruld on frish wather."

EPITOME OF THE HISTORY OF THE WATER SUPPLY OF NEW YORK.

In 1613 a small Dutch colony established itself on Manhattan Island. The colonists constructed a small fort and a few cabins. Water was supplied by means of wells, from which it was hoisted with ropes or balanced poles.

Water was supplied in this manner until 1658, when a public well was dug in lower Broadway. This supply, with private wells, lasted for fifteen years later, or until 1673, when additional public wells were added, bringing the total number up to nine.

By 1748, or one hundred and thirty-five years after the earliest occupancy, these wells were recognized as foul or contaminated, and much of the drinking supply was hauled from the "Old Tea Water Pump" and other sources supposed to be pure and wholesome.

The water wagons hauling from this pump so obstructed foot traffic that in 1797 the pipe was raised to permit people to walk under it.

By 1774 the population had reached the figure of 22 000, and increased water supply was attempted by the construction of reservoirs on the higher parts of the island, and pumping water into them from wells grouped around a fresh water pond known as "The Collect," situated near Leonard and Center streets. For this purpose £11 400 at 5 per cent. interest were expended. The works, consisting of this group of wells, pumps, reservoirs and bored logs for pipes, were completed in 1776. The water was insufficient and the works were soon abandoned.

In 1786 the first attempt to get control of the water supply was made by a private corporation. The town authorities were induced to call for proposals for furnishing water. The proposals were submitted, but such indignation was expressed at the action of these authorities that the proposals were returned unopened.

During the next twelve years, or until 1798, various projects were discussed. In these discussions Dr. Joseph Browne, a very broad-minded and far-seeing citizen, took the advanced position that the water supply contained "the germs of diseases," and strongly advocated bringing in water from Bronx River. He urged, in 1798, one hundred and nine years ago, that "the health of a city depends more on its water than on all the rest of its eatables and drinkables put together," a truth which the authorities at the present day cannot afford to disregard.

In February, 1799, the Bronx plan was about to be carried out. In this it was proposed to introduce 3 000 000 gal. daily, the works to be constructed and owned by the city. The necessary authority was asked of the state legislature. Instead of granting it, that body came to the remarkable conclusion that the granting of such authority to the city was "doubtful"; and, instead, granted a far more doubtful charter to certain speculative gentlemen, headed by Aaron Burr, constituting a corporation known as the "Manhattan Company." This charter conferred other rights than furnishing water. Under these rights this company entered into the banking business. They did not carry out the Bronx system which, by implication, they were obligated to do, but instead dug a well near Center and Chambers streets, constructed a reservoir and laid some 23 miles of wooden pipe. Under the charter thus obtained the great banking institution known by this company name yet maintains its charter and business as a bank by pumping water from a well in this neighborhood into a nearby stone reservoir.

In the manner above described New York was partially supplied with water until 1830.

In 1829 the city again undertook the construction of public water works by building a reservoir and pumps and laying 12-in., 10-in. and 6-in. mains therefrom, principally for fire protection.

During this period water supply was very unsatisfactory, and various attempts were made to secure the Manhattan Company's works for the city.

The city had evidently learned a lesson of import in this struggle, and, in 1830, several projects were under consideration:

(1) Rye Pond (Bronx).
(2) Croton River.
(3) Passaic River.
(4) Wells on the island.

In 1832 the ravages of cholera emphasized the importance of a pure water supply. It is instructive to review the conditions existing about that time: Water was furnished by wells, most of them polluted by an occupancy of two centuries. Yellow fever and cholera had scourged the city; the ravages of other waterborne diseases had been severe. From a quarter to a third of a million dollars per year was spent in buying water, brought from supposed uncontaminated sources, at 2 c. per gal. Brooklyn spent about $50 000 per year in the same way. Thus the price

of using impure water was paid not only in dollars and in the depreciation of property, but in the lives and health of the citizens.

Finally, in April, 1835, the proposition to bring Croton water into New York was carried by a vote of 17 330 against 5 963.

Ground was broken in May, 1837, or a little over two years later, the intervening time having been necessary to mature plans and let contracts. Water was turned into the reservoirs and mains on June 27, 1842, and in November, 1848, the high bridge over Harlem River received its finishing touches and the works were completed. The total cost was $12 000 000, and the volume of water made available from the Croton watershed of 360 sq. miles was 60 000 000 gal. per day, since forced to much more than this.

It became apparent within the next third of a century, or during the latter half of the seventies, that even this supply had become inadequate, and for some years additional sources were considered.

So rich a prize as the supplying of a vital necessity to the great metropolis of America did not fail to attract attention. So again, in 1887, a scheme was conceived to wrest the control of this supply from public ownership and put it in corporation control. In that year the Ramapo Water Company was organized, ostensibly for manufacturing and mining purposes. Subsequently this act was amended to permit this company to supply water to any municipality in the state of New York. Three years after the organization of this company was effected the general law under which it had originally been organized was repealed and immediately reënacted, throwing legal safeguards around contracts made with companies supplying water. Subsequent legislative action still further strengthened the Ramapo Water Company by conferring privileges upon it which were specifically denied the city of New York. This great municipality was still further crippled by the insertion of a clause into the charter of Greater New York by the legislature forbidding that city from taking water from a source devoted in whole or *in part* to the supply of any other municipality.

The Ramapo Water Company had not been idle on other lines. It laid claim to nearly every possible source of water in the state of New York.

Its corrupting influences were not confined to the legislature, for its officers proceeded to draw up a contract between the water commissioner and the Board of Public Improvements

of Greater New York and the Ramapo Water Company, which contract, if signed by the commissioner and approved by the Board, would give the company complete control of the New York water supply. Under the able tutelage of this company, the legislature had already passed the laws necessary to confer these powers upon the officers above named and to make their action binding upon the taxpayers of Greater New York.

To make the necessity for prompt action more apparent, the existing water supply of New York was lavishly — nay, criminally — wasted.

"On August 16, 1899, Mr. William Dalton, commissioner of water supply, presented to the Board of Public Improvements for approval a certain proposed contract between the city of New York and the Ramapo Water Company." (Pres. Wm. F. King's Report to the Merchants' Association of New York, p. 23.)

Commissioner Dalton strongly urged the adoption of the contract and was favored by a majority of the Board of Public Improvements.

Petitions were submitted to this board purporting to be in support of this contract. These petitions were signed with the names of more than a thousand firms and business men of New York. It was subsequently found out that the majority of these signatures had been fraudulently obtained or used or were spurious.

The piratical work of the buccaneers and pirates of the Spanish main was mere child's play beside the purposes and plans of the Ramapo Water Company. These purposes and plans were intended to lay the great city of New York under tribute to that company in the amount of $195 000 000 in forty years; at the end of which time the city would doubtless be more securely in its power. Fortunately, there was in the Board of Public Improvements at that time one man who temporarily blocked this nefarious scheme, until, through injunction suits, the backing given him by the Merchants' Association of New York and Governor Theodore Roosevelt, the entire plan was thwarted. That man was Mr. B. S. Coler, comptroller of the city. The result of his stand is the continued ownership of the supply by the city.

As Greater New York now stands, less than one half of 1 per cent. of the water of the boroughs of Manhattan and Bronx are supplied by a private company, the rest by the city. Ninety-three per cent. of Brooklyn is supplied by the city, the remainder by private companies. Queens is supplied largely by wells, 30

per cent. owned by the city, 70 per cent. by individuals and private corporations. Richmond yet depends upon wells, either private or by private corporations.

Steps are being taken to still further increase the Croton storage by small reservoirs and to bring in additional supplies.

The engineering works are set forth in full in the excellent reports of Freeman and Wegmann and in the reports embodied in the history of the water supply of the city of New York by the Merchants' Association. From these reports, and from several inspections of the New York works by the writer in 1875 and 1904–5, the above very brief history is compiled.

At present a commission of engineers is engaged in developing a far larger system and making studies as to purifying the supply which, under any circumstances, must be drained from populated areas.

Thus, in the history of New York's water supply, three notable attempts have been made to secure control by corporations:

The first in 1786, when the city authorities were persuaded to ask for proposals for supplying the city with water. These proposals were submitted, but the storm of protests against the proposition caused these proposals to be returned unopened.

The second attempt was made in 1799, when the glittering prize of a banking establishment was concealed in the charter granted by the legislature. The water supply was only a secondary proposition in the scheme and practically perished after some years of monopoly control.

The third attempt by the Ramapo Water Company culminated in 1899. This company succeeded in corrupting the legislature and some of the city authorities, but was defeated before consummating its purposes. This attempt was so skillfully planned, pressed with such total disregard to honesty and was ultimately so thoroughly exposed and defeated, that the capture of New York's water supply will probably never again be attempted.

Brief Outline of the History of the Water Supply of San Francisco and of the Efforts to Attain Municipal Ownership of the Same.

Upon the settling up of the peninsula in 1849–50 the necessity of a water supply was met by springs and wells at several points within the limits of the city. The soil being unpolluted,

these nearby sources were safe, but soon failed to meet the rapidly growing demand. Water was then brought from springs and streams in Marin County and distributed to homes, restaurants, hotels, shipping, etc., in buckets and casks (as is now being done).

In 1851 the Mountain Lake Water Company undertook to bring the water of Mountain Lake and Lobos Creek into the city, and made a contract with the city of date June 1, 1851. (City Manual, page 117, Ordinance No. 167.) This ordinance was amended and the time extended from time to time.

In 1857 the San Francisco Water Works was organized and succeeded in bringing in the water of Lobos Creek around the shores of Golden Gate, by tunnel through Fort Point, and flume to Black Point, where it was pumped to suitable elevations. Water was introduced on September 16, 1858.

This company and the previous one, the Mountain Lake Water Company, had numerous suits at law. The Mountain Lake Water Company failed in 1862 and went out of business.

In the meanwhile George H. Ensign organized the Spring Valley Water Works under a charter obtained from the legislature. He took up a small spring near the intersection of Mason and Washington streets and laid a few pipes in 1858. He kept this franchise alive by extensions of time until 1860, when it was bought by a stronger company. (This company retained the name of Spring Valley Water Works until 1904, when for the purpose of overreaching the state law, which limits the bond issue to the amount of stock, it doubled its capital stock so as to issue an equivalent volume in bonds. It then changed its name to Spring Valley Water Company.)

The stronger company organized in 1860 proceeded at once to actually bring in a supply from San Mateo County and introduced 2 000 000 gal. per day from Pilarcitos Creek in 1862.

Litigation. — There then existed the two companies: (1) The old San Francisco Water Works, bringing in its supply from Lobos Creek *via* Fort Point to Black Point and pumping into reservoirs and mains. (2) The reorganized Spring Valley Water Works, bringing in the gravity supply of 2 000 000 gal. per day from Pilarcitos *via* Lake Honda. There was no litigation and no trouble about water for municipal purposes. But in February, 1865, the two companies "consolidated," or the Spring Valley Water Works "bought out" the other. In 1867, or two years later, there commenced the series of litigations which have continued until the present, notably the ten years' litiga-

tion in which the city won the somewhat barren victory under the late John F. Swift, and the litigation now in progress in the United States courts, ostensibly for adjusting rates, but evidently to get a high valuation fixed for either rates or selling out.

This Lobos Creek supply continued to furnish between one and two million gallons per day until 1895, when it was abandoned. In 1901, after several dry seasons, it was reintroduced by pumping it into the Richmond district mains, but was so foul that the company was forced to abandon it a second time.

As the demand grew with increasing population and use, San Andreas, having a drainage area of 3.8 sq. miles, reinforced by the diversion of an additional square mile, was introduced.

These sources proved insufficient, and following the dry season of 1876–7 pumps were hurriedly erected and the water of Lake Merced was pumped into the previously constructed conduits, and Upper Crystal Springs dam was commenced. The history and function of this dam is interesting.

It was evidently intended to make it appear that the site of the Lower Crystal Springs dam was not needed, for it was "gradually completed" in 1890–1, or was about sixteen years in construction. In the meanwhile, Lower Crystal Springs dam was commenced, but work was not pushed, and the critical period of 1886–8 caused the introduction of the Alameda Creek supply through two 16-in. submerged pipes from Dumbarton Point to Ravenswood, whence it was pumped into the Crystal Springs main. By 1890 Lower Crystal Springs dam was raised to a sufficient height to supply water. It was subsequently raised, and under ordinary conditions brings the peninsula supply to about 20 000 000 gal. daily (exclusive of Lake Merced supply, which is of very questionable quality).

In 1887 it was necessary to go to Alameda County for an increased supply, and since that date all increased supplies have been directed to a further development of that source.

In 1901 the two 16-in. submerged pipes were supplemented by two 22-in. mains. Artesian wells were sunk in Pleasanton Valley and galleries constructed in Sunol gravel beds. These reinforcements brought the supply up to about 35 000 000 gal. per day. And to provide for a possible shortage, wells have been sunk near Ravenswood, connected with pumps, so as to drain the gravels in San Mateo and Santa Clara counties.

The "system" of supply as it now stands has been the result of a growth stimulated by two causes: (1) To meet from the most available source the increasing demand; (2) to acquire

competing properties or projects and develop or hold them as occasion has required or may require. These two causes have gone on together, and it is difficult to completely segregate the investments and developments due to each. The result is a group of individual sources linked together by interconnections of a rather complicated character, but answering to the general term "system," in which the mode of origin and development of Mrs. Stowe's character "Topsy" is suggested. The various parts have been worked into a water supply for a city of nearly a half million people and property values of over half a billion dollars in a manner both unique and original, partly the result of design and partly of force of circumstances.

The commencement of work on Lobos Creek by the Mountain Lake Water Company in 1851 was apparently done to meet the first requirement. The organization of the San Francisco Water Works in 1857 was a well-planned and successfully executed scheme to uproot the former company. The organization of the Spring Valley Water Works in 1858 was a speculative scheme pure and simple, and for two years, or until purchased by a strong company in 1860, was carried on merely to hold a franchise. In that year this franchise was purchased by a group of capitalists, who retained the name and undertook to supplant the San Francisco Water Company by introducing water from Pilarcitos Creek in San Mateo County. This was done two years later, in 1862.

Until 1865, when the Mountain Lake Water Works succumbed and were bought out by the Spring Valley Water Works, there was competition in the supply and peace in municipal circles. But only two years later, or in 1867, litigations began, and there has been practically no peace since, the most quiet times being instances of "armed neutrality" on each side, with "system," intrenchments and heaviest guns on the side of the monopoly, and disorganized and unsustained effort on the side of municipal ownership.

But in this struggle, the greatest of its kind in the water supply of American cities, and extending over a third of a century, the city has frequently attempted to gain ownership of its water supply. The history of these attempts will now be briefly reviewed:

The first investigations of the water supply, conducted by the city with a view to municipal control, were made in 1871–2. The dry seasons, 1869–70 and 1870–71, emphasized the necessity of an increased supply, and on April 10, 1871, the Board of

Supervisors appointed a special committee on water supplies to investigate and report on the subject. This committee consulted Gen. B. S. Alexander, Corps of Engineers, U. S. A., and Prof. George Davidson, U. S. Coast Survey, and reported, December 11, 1871 (Mun. Rep., 1871–2, p. 626 *et seq.*), "that the water sources of the peninsula, within reasonable distance, are amply sufficient to furnish an abundant supply of good, pure, fresh water to provide for the wants of San Francisco for at least fifty years." *

Also, "that the city should own and have absolute control of the water works is a fact self-evident, and requires no favorable argument from us. The success and admirable management of the great water works of New York, Boston, Philadelphia, Chicago, Washington and other large cities in our own land afford satisfactory experience ample to vindicate its necessity and expediency in our own case."

General Alexander concluded, upon the basis of yield of Pilarcitos watershed, that from the 60 sq. miles on the west slope of the peninsula drainage, 20 244 000 000 gal. could be developed, which, with the yield of Canada de Raymundo, could be raised to 21 979 000 000 gal., or a daily supply of 60 216 434 gal. But he did not point out reservoir capacity for such a supply.

Professor Davidson, who in 1869 had been called upon to report upon the supply of the then San Francisco Water Company, confirmed the conclusions he had then reached, namely, that the peninsula supply was sufficient for 1 000 000 inhabitants.

These plans involved a storm water canal along the west slope of the peninsula, a tunnel through the ridge and storage capacity far beyond any yet developed. The succeeding season, 1871–2, was exceedingly wet and no action was taken upon this report.

The seasonal rainfall of 1872–3 again fell far below the average, and the subject of municipal ownership was again agitated. This resulted in the misdirected and unfortunate steps taken in 1874–5, when the city undertook the "Scowden Surveys." During these years Blue Lakes in the Sierra, Clear Lake, Calaveras Creek and the peninsula sources were surveyed and examined. The resulting report and recommendation favored the acquisition by the city of Calaveras Creek, draining

* Yet in 1887, or fifteen years later, an additional supply was introduced from beyond the peninsula, or from Alameda Creek via the Dunbarton Point submarine pipes, as previously recited.

the northwest slopes of Mount Hamilton and adjacent outliers to the north and forming the principal tributary of Alameda Creek, and subsequently known as "the Calaveras cow-pasture scheme." Despite the rather flat and cold reception of this recommendation, the city was negotiating for the purchase of the alleged rights from the proponents of this scheme when the Spring Valley Water Works, fearing competition, forestalled the city's action by the purchase of these rights and properties in May, 1875. (Mun. Rep., 1874–5, p. 684.) The moves in this scheme appear to have been planned to force the sale of these properties, either to the city, as a source, competing with the Spring Valley Water Works, or to this company, to prevent competition. This latter result was accomplished. Since 1875 these properties have been held as an undeveloped resource of the Spring Valley Water Works, or its successor, the Spring Valley Water Company, although brought forward from time to time as about to be developed.

The sale above mentioned effectually put a stop to the proposed acquisition of municipal water works, and the very wet season of 1875–6 quenched still further the feeble embers of this attempt.

But varying climatic conditions seem to affect the moods of San Francisco as to water supply, and the dry season of 1876-7 severely taxed the then existing supplies and again caused hurried efforts to be put forth by the Spring Valley Water Works to meet the demand. The city again, and on far broader lines, undertook to investigate the possibilities of existing and auxiliary sources.

In 1876–7 there was conducted a series of surveys and examinations under the late Col. George H. Mendell, Corps Engineers, U. S. A., embracing all the sources which had been brought forward up to that time, and several additional ones. Offers of these were made to the city, as well as of the Spring Valley sources and properties. The sources examined were:

(1) Existing supplies and undeveloped sources claimed by the Spring Valley Water Works.

(2) Clear Lake.

(3) Lake Tahoe.

(4) El Dorado Water and Deep Gravel Mining Company's water properties and rights. (South fork of American River.)

(5) Blue Lakes. (Mokelumne River.)

(6) Mt. Gregory Water and Mining Company. Rubicon River. (South fork of middle fork of American River.)

(7) San Joaquin and San Francisco Water Works.
(8) Feather River Water Company.
(9) Lake Merced. (Donahue, Sharp & Mahoney.)

The Spring Valley Water Works offered its properties for $16 000 000. The city made a counter offer of $11 000 000, which was declined. The proposition of municipal ownership was defeated by the proprietors of certain newspapers, who demanded that they be paid for advocating the purchase. The city then proposed to carry out the Blue Lakes scheme, but abundant rains and the completion of Upper Crystal Springs dam in the immediately succeeding years diverted public attention from the matter, not again to be taken up until the dry season, 1897–8, and succeeding seasons of deficient rainfall, and by the charter provision making it obligatory upon the supervisors to make attempts every two years to acquire this necessity.

The charter went into effect on January 8, 1900. During that year and the succeeding one the Board of Supervisors caused to be made by the Board of Public Works and the City Engineer an exhaustive study of the whole subject, taking into consideration all available sources of supply and the future needs of the city. These examinations and studies embraced:

(1) The Spring Valley Water Works' Supplies.
  (*a*) Lobos Creek.
  (*b*) Lake Merced.
  (*c*) Pilarcitos.
  (*d*) San Andreas and Crystal Springs.
  (*e*) Portola.
  (*f*) San Gregorio and west slope drainage.
  (*g*) Alameda Creek.
  (*h*) Pleasanton wells.
  (*i*) Sunol gravels.
  (*j*) Calaveras Creek.
  (*k*) San Antonio Creek.
(2) Lake Tahoe.
(3) Yuba River.
(4) Feather River.
(5) American River.
(6) Sacramento River.
(7) Eel River.
(8) Cache Creek (Clear Lake).
(9) San Joaquin River.
(10) Stanislaus River

(11) Mokelumne River.
(12) Tuolomne River.
(13) Bay Shore gravels.
(14) Bay Cities Water Company's resources.

The result was that the Tuolumne River, draining 1 501 sq. miles of the west slopes of the Sierra Nevada mountains, receiving a mean annual rainfall of 20 to 50 in., and having a mean annual runoff of about 24 in., or nearly 2 000 000 acre-ft., was selected. This source presents the following unrivalled advantages:

First. Absolute purity by reason of the uninhabitable character of the entire watershed tributary to the reservoirs and largely within a forest reservation.

Second. Abundance, far beyond possible future demands for all purposes.

Third. Largest and most numerous sites for storage.

Fourth. Freedom from complicating "water rights."

Fifth. Power possibilities outside the reservation.

It has the drawback of distance to overcome, requiring the construction of conduits aggregating 142 miles in length. But considering the partial pollution and the rapid rate of pollution to which all other sources may in the future be subjected, particularly nearby sources, the Tuolumne River is far superior to any other.* There is, however, one almost insurmountable obstacle. There are no private interests to be served by the acquisition and development of this source.

The reservoir sites filed upon are: (1) Hetch Hetchy, on Tuolumne River, developing, with a dam 150 ft. high, 89 000 000 gal. per day for the year without drawing on the discharge of the river at the intake of the canal; and, 135 000 000 gal. per day by drawing on the river when its discharge is above the possible limits of future draughts. The tributary drainage area is 452 sq. miles, varying from 5 000 to 13 000 ft., uninhabitable and presenting throughout ideal conditions of purity; (2) Lake Eleanor, on the creek of same name, and developing 57 000 000 gal. per day for seven months of the year. The tributary area is from 4 700 to 12 000 ft. in elevation and 84

* The engineers reaching this decision had a combined personal and professional knowledge of the available sources aggregating more than one hundred years, and no well-informed and unprejudiced member of the profession has as yet even partially investigated the subject without endorsing the wisdom and soundness of the selection.

sq. miles in extent, uninhabitable and presenting likewise ideal conditions of purity. An additional area of 103 sq. miles from Cherry River and of the same character can readily be made tributary to Lake Eleanor, and its storage greatly increased by a higher dam.

There are thus over 630 sq. miles of the most ideal catchment areas tributary to these matchless reservoirs, and the capacities of these reservoirs are capable of being doubled by dams well within the possibilities of the sites and tributary areas. Moreover, the discharges from these areas are far in excess of the maximum capacities of the reservoirs, and other excellent reservoirs are available throughout the drainage area for such other industries as future needs may require. Under maximum reservoir development there must still be a large waste from the Tuolumne watershed.

The two reservoir sites necessary to utilize a portion of the waste flood waters from this source were surveyed, filed upon and application for the necessary rights made to the Department of the Interior. These rights, by reason of the lack of a precedent, were not applied for in the name of the city, but in that of its mayor, who transferred them to the city. It was considered necessary to make these surveys "surreptitiously," but the laws and regulations controlling the mode and time of making them were complied with. If it had been known that the city authorities looked to the waste waters of Tuolumne River as a source of supply, the legalized blackmail of a prior applicant or appropriator would have been put in force; as these can move more rapidly than the city, trammelled as it is by the requirements of the charter and laws. As the result, these rights were filed upon without further cost to the city than those imposed by law.*

These rights were denied by the Secretary of the Interior on January 20, 1903. He later granted a rehearing, and again denied them December 22, 1903, alleging that the law of October 1, 1901, did not authorize such grant and suggesting an appeal to Congress.

---

* Since these filings were made, some five or six "locations" and "filings" have been made by private parties and corporations looking most probably to the time when this city or some one else will have to "buy them off." But if the city's applications be granted, no other rights, either prior or subsequent to April, 1902, will have to be acquired. Only rights of way for pipes and small properties within the reservoir space will have to be acquired.

Strong opposition was put forward to the granting of these rights, notably by the Spring Valley Water Company, which sent its Chief Engineer on to Washington, and he obtained an audience with the Secretary of the Interior and appeared in opposition to the application of the city before its officers were apprised of such audience and prior to the date set for the rehearing. This company also, through and by the same officer, worked up a strong opposition in Modesto and Turlock irrigation districts, making extravagant and false representations to the landowners of these districts, some of whom, under his able tutelage, have made and published statements to the effect that San Francisco's utilization of waste water from this source "would ruin their homes and farms and convert them into deserts."

When it is considered that these districts aggregate 402 sq. miles and that the mean annual run-off of 2 ft. from 1 501 sq. miles would cover the districts with between 3 and 4 ft. of water, in addition to the 12 in. they generally receive, and that no possible development could economically make use of the above run-off, the unreasonable and false character of these objections is manifest.

Upon the denial of these rights in December, 1903, a bill was drafted and introduced in Congress and referred to the Committee on Public Lands. This bill and its sponsors, the representatives from San Francisco, could get no standing before this committee.

The city authorities, not satisfied with the ruling of the Secretary of the Interior, presented the matter to the President in February, 1905. He, not knowing the complications of San Francisco water matters, unfortunately referred the matter to the Hon. the Secretary of Commerce and Labor. That official rendered an opinion which, for illogical conclusion, will stand as a shining example. He completely overthrows the basis upon which the Secretary of the Interior founds his denials, but expresses his concurrence in and justifies such denial. The city and county attorney, still dissatisfied with this opinion, caused the matter to be again brought to the attention of the President, who furnished the city and county's representative with copies of the correspondence and requested that the argument for the city be presented in such form that it could be referred to the Attorney General of the United States.

On July 27, 1905, an elaborate statement and argument for the city was placed in the hands of the President; but one

of the secretaries, not knowing the exact nature of the paper, again referred it to the Secretary of the Interior. Upon having attention called to this error, the paper was recalled and referred to the Attorney General.

On October 28, 1905, that official rendered an opinion in which he advises the President as follows. He quotes the law of February 15, 1901 (31 Stat. 790), providing for rights of way through certain parks:

" 'That the Secretary of the Interior be authorized and empowered, under general regulations to be fixed by him, to permit the use of rights of way through the public lands, Yosemite, Sequoia and General Grant national parks, California, for . . . canals . . . *reservoirs* for . . . the supplying of water for domestic, public or any beneficial uses.'

" I have carefully considered the language of the act as above quoted and am clearly of the opinion that Congress thereby intended to vest in the Secretary a discretionary authority to grant or refuse applications of this kind.

" I would, therefore, respectfully suggest that, if you desire further consideration or different action, the matter may be taken up with the Secretary of the Interior."

No notice, so far as the writer is aware, was furnished to the city or its advocates of this letter until it was unearthed by Mr. James C. Hooe, of Washington, at the request of Hon. James D. Phelan, during April, 1906.

Between the decision of the Attorney General of the United States that the existing law of February 15, 1901, was adequate, and the publicity of this opinion in May, 1906, the Board of Supervisors passed Resolution No. 6949 of January 24, 1906. This was at once seized upon by Mr. J. C. Needham, congressman from the sixth district of California, who represented to the Secretary of the Interior that Resolution No. 6949 was an abandonment of San Francisco's rights under the application of April, 1902. This was denied by the Board of Supervisors, but subsequent actions proved this denial to be merely a subterfuge.

The history of steps lately taken is so fresh in the minds of the public that but a brief reference to it is necessary.

The Board of Supervisors in the beginning of 1906 practically had before them the whole subject. A New York promoter, Mr. Cragin, offered as an auxiliary source to the existing supply El Dorado Deep Gravel and Water Company's properties on the south fork of American River, reinforced by the stored

water of Echo Lakes, diverted by tunnel from Lake Tahoe drainage basin. The offer was for $35 000 000 and included the present source (whether by authority or not is not known to the writer).

This offer was not definitely considered. The Bay Cities Water Company, which had previously submitted a project to supply water from the slopes adjacent to Santa Clara Valley, then submitted a proposition embracing the South Fork properties of the El Dorado Company and certain rights to reservoirs and claims on Cosumnes River. This proposition was reported upon by the City Engineer in July, 1906. From his unpublished report the following is summarized:

The sources offered are of two characters:

(1) The stored and flood waters from Silver Fork, Slippery Ford Fork, Silver Lake and Echo Lakes; pure and desirable waters now in use in and around Placerville.

(2) Stored and flood waters of Sly Park and Buck's Bar, reservoirs draining from inferior areas, large fractions of which are in private ownership.

The total drainage areas on the South Fork are 243.5 sq. miles, of which only 44 sq. miles are tributary to storage within its basin. The run-off from the remaining 200 sq. miles must be diverted by canal and tunnel between 18 and 19 miles long into the drainage basin of Cosumnes River for storage. It is manifest that a large portion of the run-off thus proposed to be utilized must be lost, as a mountain canal to divert the maximum discharge is not reasonably practical.

On Cosumnes River and tributaries there is a total drainage area of 160.51 sq. miles, of which 14.43 sq. miles are tributary to Sly Park reservoir, and the remainder, 146.98, to Buck's Bar reservoir. The run-off from these areas must be reinforced by that from South Fork of American River. This brings into service about 404 sq. miles of drainage area, about one half of which must be utilized by diversion canals, and one fifth of which is in private ownership, with several villages, the sewerage of which must by gravity flow reach the lower reservoir.

The conditions, therefore, granting that the complicated rights and titles shall be settled advantageously, are not comparable to the 635 sq. miles of uninhabitable area tributary to Hetch Hetchy and Lake Eleanor reservoirs of the Tuolumne.

The Bay Cities properties and claims have been thus fully presented and compared for the reason that the present Board of Supervisors have rejected all other sources and selected this

one at the price offered, namely, $10 500 000, as the one to be offered to the voters of the city.

The Board of Supervisors in 1902–4 called for offers of the Spring Valley Water Works and properties. But the requests were either technically avoided or ignored.

There have thus been four attempts by the city to gain possession of its water supply: (1) in 1871–2; (2) 1874–5; (3) 1876–7; and in 1900–6. What the result will be depends upon the intelligent and unselfish action of its citizens and officials. But judging from the supreme indifference with which the majority of the citizens of San Francisco look upon the situation, and the skill and cunning with which corporate control is managed, there appears little hope for any betterment either in the purity and abundance of the supply or the rate at which it is furnished.

There were gross and irremediable blunders made by the Spring Valley Water Company in sending its chief engineer on to Washington to oppose the applications of the city for reservoir rights of way, and in the importation of false representation of facts into the Modesto and Turlock irrigation districts. It is possible that the more thoughtful and far-seeing of its officers realize these blunders. Such methods have convinced many conservative minds, previously inclined to treat openly and generously with the company, that they have an unscrupulous monopoly to deal with, which is ready to adopt any means to thwart the ultimate good of San Francisco for its own selfish ends. The effect of this action may prolong monopoly ownership of this necessity, but it may eventually be the crowning act which will cause Sàn Francisco voters to select some other source.

The Struggle for Purity.

In addition to the struggle for ownership, there is going on a more vital one for the purity of the supply. As the regions around our great cities inevitably become more densely occupied, the sources once pure become polluted. Whether this pollution comes from denuded mountains, cattle ranges and pastures, from farms and barnyards, from villages and towns, or from manufactories and mines, the results are to render the earlier selected sources unfit for domestic use. Not until the penalty is paid in human suffering and death is this pollution remedied, and even then the cost in dollars is frequently pitted against the cost in lives, at the expense of the latter. In notable instances on

this coast, such as Portland and Seattle, the lesson is thoroughly learned and the purest water, at any cost, is introduced, with a result which these cities would not exchange at any price.

The remedies lie along five general lines: (1) A change of source, as in the instances just cited; (2) storage of a partially polluted supply and exposure in the reservoir for as long a period as possible, as in Boston, New York, Baltimore, Richmond, etc.; (3) sand filtration, as in Berlin, Washington and as under way in Philadelphia, etc.; (4) sedimentation and treatment with flocculents or astringent salts of iron or alumina, and precipitating these with lime, etc.; (5) bactericidal processes involving the use of ozone.

If the first of these can be satisfactorily accomplished by the utilization of an uninhabited or sparsely settled area or a deep underground supply, it is far preferable, as a water supply which does not require a chemist's and a bacteriologist's certificate as to purity is best.

(2) Storage in reservoirs for at least two seasons is satisfactory where the drainage area is reasonably clean, but easily borders on the dangerous, as in Baltimore.

(3) Sand filtration, where properly applied, is highly satisfactory, but costly, and requires the most conscientious and skilled care.

(4) The same is true of treatment with flocculents.

(5) The use of ozone has been found highly efficient in France, Holland, Belgium and Germany, and a test plant in Philadelphia thoroughly purifies 1 000 000 gal. per day of the highly dangerous water of Schuylkill River. The prime element in this process is the cheap generation of ozone. The efficiency is unquestioned when compared even with sand filtration.

On all of the purifying methods the engineer is confronted by innumerable patents; even in the old sand filtration process there are recent patents for preliminary filtration, modes of removing and washing sand, etc., whilst in the use of flocculents and ozone the number of patents is legion.

In meeting the dangers and penalties of impure water, resort is had to a partial use of distilled and bottled spring waters. These are distributed in all cities to an extent which imposes a heavy expense. During recent repeated visits to Boston, New York, Philadelphia, Baltimore and Washington, the writer endeavored to get some idea of this expense. The figures ascertainable were far from complete, but indicated that not less than $8 000 000 is the annual expenditure in the cities

named, which, capitalized, represents a principal of $200 000 000. If to this be added the cost of boiling the water furnished by these municipalities, the capital would exceed the value of the combined municipal plants of these cities.

Even at this expense the consequences of an impure municipal water supply are but partly escaped.

There is just starting a struggle on new lines, namely, that against an excess of the mineral or soluble contents of the water.

It has been found that certain salts, notably of lime, alumina, silica and magnesia, when present in amounts from 20 to 35 gr. per gal. and when constantly used, result in obscure heart and kidney diseases. The former is peculiarly prevalent on this coast. These organs, under the constant strain of eliminating or of working under the disadvantage of an excess of mineral matter in the blood, yield in middle age to these fatal troubles. It has long been considered profitable to remove these salts from water used in boilers, but to remove them from the water consumed in the more delicate human system is not profitable in coin and is only paid for in life and health.

Many regard 40 gr. per gal. as a safe limit, but the writer is inclined to reduce this limit to one third or even one fourth this amount, if reasonably possible.

The great improvement in health in Portland since the introduction of water of the highest standard of purity warrants this rigid limit.

This struggle is, therefore, not ended when a city gains control. New York had the battle of its life to prevent the Ramapo Water Company from wresting control from its hands and placing an enormous tribute upon every home and every industry within its borders. San Francisco's struggle, we have seen, commenced in 1871 and appears no nearer an end at the dawn of 1907.

In all of these struggles it is manifest that the source of political corruption is not in official life, but in the body politic, in the ranks of those who pose as good citizens and, as directors and officers of great corporations, enjoying or desirous of securing monopolies, prey on the public through the non-official "political boss."

This creature is not the natural product of our political system, but the outgrowth and necessary adjunct of monopoly. When an official is false to his trust, there is almost always this go-between, this procurer, and his master the holder of or the seeker for a monopoly.

In New York it was the firm stand of one official that saved that metropolis its water supply. He fought alone until the public could come to his aid, and it took years of struggle to win.

In San Francisco it has been and is incivism and neglect of public duty which has lengthened out the fight over to a third of a century. However zealous groups of officials may have been at various stages of this struggle, the indifference of the public generally is the true cause of our repeated failures. This indifference is taken advantage of by those who have, or believe they have, rights for sale to the city.

We have a marked example in Oakland, where, after a judicial determination of the value at a figure probably double the actual investment, the "works" have been "capitalized" at nearly six times the judicially fixed value.

Whether a similar fate awaits San Francisco remains to be seen, although the existing works are already capitalized at a figure sixteen millions of dollars greater than the cost of the best of the Sierra sources.

In conclusion: Since these affairs are undertaken in our country only when a majority of the voters has knowingly or ignorantly expressed its decision, the details of these struggles should be known to every citizen of every municipality. These details are essential facts of which he must be cognizant in order to form a correct judgment as to the most important function which his municipality has to perform. When it is considered that "the health of a city depends more on its water than on all the rest of its eatables and drinkables put together," that the health of successive generations of mothers and children depends upon the purity of the water supply of the home, then, indeed, does the source of this water become to the civil engineer "the holy of holies." Then does this prime factor, *purity*, stand forth in strong light, and the minor factors — What does it cost? What per cent. do the stock or bonds yield? — shrink into insignificance. When these factors are considered in their true relation, municipal ownership of this necessity of existence and health is the only solution. The smaller questions of street railroads, telephone, gas and electric power can well be let alone until a city can say, *We own our water supply. It is pure and its sources unpollutable; it is abundant in every home within our limits.*

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk St., Boston, by May 15, 1907, for publication in a subsequent number of the Journal.]

REPLACEMENT OF BRIDGES AND ALLIED STRUCTURES.

By Herman K. Higgins, Member Boston Society of Civil Engineers.

[Read before the Society, January 23, 1907.]

The writer was for several years in the employ of a railroad company. Part of his duties consisted in the examination of structures for the purpose of determining, first, when they should be replaced; second, what loads they should be allowed to carry in the meantime. Some of the conclusions he has arrived at may be pertinent and possibly useful.

Many of us (the writer included) are accustomed to consider bridges as classified, (*a*) by material, — stone, concrete, iron, wood, etc., — and (*b*) by use, — highway, railway, etc. In the olden time when the writer was forming his bridge habits (many of which he has found occasion to change) the classification by use was characteristic, — highway bridge practice being materially different from railway practice. Since the advent of interurban street railway and motor vehicles the distinction has largely disappeared, and in many respects the two classes are now practically one.

Classification by material is still to a great extent characteristic, although the lines of demarkation are becoming much less sharply defined. The reinforced arch, for example, is neither like a stone arch which it resembles in appearance, nor like a plate girder nor a continuous column, which it resembles (somewhat) in stress analysis.

The writer has in recent years thought of bridges as classified thus:

1. Stone, voussoir arch, including brick, and block concrete. 2. Concrete, monolithic, hinged or not, reinforced or not. 3. Iron or steel, with floors of any material. 4. Wooden, with only part of tension members of metal and with bolts, spikes, etc., of iron or steel.

These four classes call for somewhat different treatment in detail, the general considerations remaining the same for all.

The determination of the proper time for renewal of a structure ("structures" being a term to cover many things besides bridges) is a much more complex problem than is often supposed. It depends upon design, condition, present loads,

probable future loads, maximum *v.* ruling loads, and last, but not least, on many economic considerations.

In order to judge intelligently and get the full life of structures a comprehensive system of inspection with reports and permanent records is necessary. Many structures likely to be condemned under irregular inspection would be retained under a regular system of examination and recorded reports. It will readily be seen that in the nature of things this must be so. If the inspector knows that he will see the structure again in six months or a year, he can work much closer to the full useful life of his material. If he does not know when the structure is to be next examined, he will, properly, condemn everything that falls below a high standard even when he knows it is good for one or possibly three years but not longer. A proper system of records also allows him to devote an extra proportion of attention to older structures. There is a chance for much waste right here in the absence of system.

Stone bridges, also brick, were, not so very long since, thought to be permanent. The older arches are, under present train and highway loads, often in need of careful watching; fortunately they always give notice of overstraining, and intelligent supervision will often hold them in service long after the stresses approach the elastic limit, indicated by cracking and spalling. These structures were designed long ago for loads then absurdly heavy but now outgrown; and loads are still growing. It may be that an occasional excessive load may be tolerated, whereas the ruling load must always be within safe limits to provide for the appreciable though unmeasurable effect of fatigue of material. It frequently is the case that very inexpensive repairs, — concrete lining, buttresses and buttress arches of brick or concrete, iron tie rods, etc., — will suffice to make the structure perfectly safe and secure for many years more, especially when economic conditions make entire reconstruction inadvisable.

Block concrete (voussoir) arches are not often met with, but compare in all respects, except unit stresses, with stone arches.

Concrete arches, monolithic, reinforced or not, are of comparatively recent date and have not yet begun to approach their limit of life. They differ from stone in that internal conditions cannot so readily be judged by external signs. It is going to be a very ticklish proposition to know just when to condemn such bridges. What knowledge we have of them is based almost entirely on laboratory tests, and the few service

tests available indicate the need of much caution. The writer does not consider it safe to approach anywhere near as close to the elastic limit as good practice warrants with either of the other types of bridges. By the time these structures approach their limit of usefulness, many, if not most, of the records pertaining to their original construction will have been lost. It is so with many old bridges built so lately that the writer can readily recall their preliminaries, and will, no doubt, continue to be the case. Roads built by promoters rarely have complete records of structures. With the original records missing, it will be impossible to correctly compute stresses, and the inspector will have no easy problem to solve. An iron or wooden bridge can be measured, a stone arch can at least be approximated, but to measure the iron in a Monier or Melan bridge will require a divining rod that will make the witch hazel of olden days look very old fashioned. Even in case the records are available the inspector's path is by no means lined with roses. The effect of vibration with modern loads is not well known nor is the quality of the concrete used. In a couple of generations this problem may be historical only, but the writer believes that most of the concrete structures of this generation will have become historical also. We need permanent records and recorded and published experience. We shall continue to build concrete structures and we greatly appreciate the experimental data prepared for us by so many eminent members of this and other societies. We could do little without it; nevertheless, we do not know nearly as much about concrete as we do about iron or stone, and as bridge inspectors we shall feel suspicious of every crack and stain, however harmless, till we can find out what caused it.

Iron or steel structures nearly always present a comparatively easy problem. If original plans are missing, they can usually be obtained from the builder, whose enterprise in advertising (by name plate) often fills a serious blank in records. The condition of the iron is apparent on proper examination. It may help some one to mention some of the locations of incipient failure. In old structures the rivets and splices usually show earliest signs of distress. Plate girders and built up beams need special attention to web rivets near ends; the hammer will not find the trouble; white paint before the last rain is much better but often not attainable; there is often some sign of motion of flange angles on webs. If motion exists, the structure should be watched for increase of motion. If it does

not increase, there is usually no cause for alarm. When it does, measures should be taken to stop it.

Lateral and sway connections are often weak and work loose; often a few rivets a size larger and some reaming of holes will suffice as a remedy.

Roller bearings that do not roll are the rule for old bridges and are important only on long spans.

If badly rusted, plate girders should be examined for holes in webs near corners adjacent to flange angles.

In truss bridges one should look for "upholstered" struts, rust streaked plates near and below riveted joints, weak details of tension members and laterals, pins subject to severe bending moment; old pins were often small and members were often put on at variance from plans. Details near bearings on masonry are often subject to excessive corrosion.

Sometimes abutments and parapets move and "pinch" the structure. This applies to all bridges, — iron and wood.

Truss pins should always have cotters outside the nuts. Old bridges usually do not. Nuts may be keyed on with machine screws. One should look for missing nuts and pins working out, also for loose rivets at floor connections, also for evidence of wear of pin at foot of hip verticals.

When the structure is known to agree with the plans, the stresses may be computed. For old structures the writer believes the best method involves the old-fashioned "wheel loads." He prefers and uses the diagram of moments in the older editions (1890) of DuBois, "Strains in Framed Structures" checked by comparison with older computations. This diagram is sufficiently elastic to use when all or few members are in question; it is little work to make a diagram for each class of locomotives as it appears on the road; it gives as close approximations as are warranted by the indeterminancy of load distribution. The writer uses graphic analysis and "equivalent loads" on design of new structures, but believes that for old structures the analytical (so-called) determination is preferable.

Unit stresses must be kept below the elastic limit even for the most occasional loads and after liberal allowance for impact has been made. In determining allowable unit stresses, knowledge of the composition and molecular structure of the metal will often provide data of great value. It is often possible to get samples for analysis and micro-examination. This must, of course, be done intelligently to be of value, and sound judgment is needed to determine when the expense of such testing will

be warranted. A soft, fibrous, homogeneous material can safely be allowed to carry loads close to its probable elastic limit, whereas a crystalline, hard or streaky specimen should have a good margin. Sulphur and phosphorus in any considerable quantity subject a specimen to serious suspicion. Manganese, on the contrary, is an element of safety if not grossly in excess.

Rivets are the most unsatisfactory and indeterminate element in the structure. Only one who saw them driven can properly judge them. The hammer and touch test is useful but not certain. The writer has seen five-eighths rivets put into seven-eighths holes and headed to give perfect appearing heads, and they were tight. The hammer was defeated as a test. The inspector (the writer) was not known to the gang and happened to see the trick done. Most of the rivets in the truss in question were planned of the small size so the danger of non discovery was real. Many, if not most, old bridges were built without inspection. What wonder that we need to examine rivets with care. The writer has also seen (not on his own work) rivets drawn down to enter a badly matched hole. With full size heads both sides, this fault is undiscoverable. After all tests are applied it is, with old bridges, a matter of faith and careful examination for evidence of movement in the joint. It will surely move before it fails and proper inspection will detect danger before it becomes imminent. Rivets rarely fail in shear. They are safe in most cases up to unit stress seven-tenths of tensile elastic limit or even more, if shop work is first class. The bearing or crippling unit stress can run much higher, nearly to the ultimate strength of the iron. The writer knows of bridge girders in service up to within a few years, the rivets in which, figured by the usual methods, were carrying pressures 25 per cent. in excess of the probable ultimate compressive strength of the iron. The shop work was extra good, iron well fitted, and friction well developed. There never was the slightest sign of distress. In such cases the writer has always considered high bearing stress on rivets rather a suspicious than a positive indication. Such structures should be watched.

The floors of iron and steel bridges need as careful examination as the main girders. The old way (still current) of using two layers of plank on highway bridges is pernicious in many places. The lower plank decays, the upper wears or decays. On city bridges, which require a new layer of wearing plank every six months or oftener, the double plank is economical and safe, as the frequent renewals of wearing plank allow

effective inspection. On town and country bridges the upper layer decays rather than wears, and the writer has usually found the lower plank in decidedly unsatisfactory condition, entirely unfit to discharge its proper function, the carrying of the loads to the stringers. The writer considers all such floors subject to suspicion and has usually recommended their replacement with a single layer of plank usually thicker than the original bottom layer. Four-inch plank is heavy enough in most cases and leaves the floor determinate.

Wooden bridges often surprise us by their capacity for carrying overloads, not safely, but nevertheless successfully in many instances.

The construction of electric railways often proves the limiting feature of wooden highway bridges, and it may well happen that the distribution of material and the moving of machinery imposes a greater strain on the bridge than the operation of the cars. These loads being rare and the cars frequent, it may still prove to be the cars that make necessary the renewal of the bridge.

City bridges are more often of iron than country bridges and are subject to corrosion in concealed places; country bridges when of iron often lack paint and corrode in exposed places.

Wooden stringer bridges usually show most decay in the middle of tops of stringers. The writer considers such decay usually not a cause for renewal until it extends far enough to cause spreading or local crushing of the stringer. This principle does not hold for concentrated loads or bearings on wall plates. These must be sound.

Timber protected from weather is subject to a form of deterioration quite distinct from decay. Builders would say, it has lost its " life," it becomes soft and punky, the grain does not separate properly. Such timber should be replaced.

Timbers of different species often destroy each other. A Howe truss with pine or spruce posts (struts) and oak angle blocks has been known to retain a mere shell of sound timber in the braces, the interior near the ends being like cheese. Only the auger intelligently used will detect this form of decay. Truss chords near oak clamps and keys will bear close examination. A chord failure usually means business for the wrecking train. Counters sometimes break short off; they need attention, especially when old.

There are often economic reasons, and political as well, which finally prove most important factors in the determination

of time of replacement. With highways the political predominates, with railways usually the economic.

It is commonly but incorrectly believed that railways keep their structures up to the requirements of their heaviest rolling stock. As most of our railways, in the East, at least, were built some time ago, it will readily be seen that there must be many antiquated structures to limit the allowed traffic. The better the structure originally was, the more likely it is to be or become a limiting feature of the road.

Most railroads, if not all, — the writer recalls no exceptions, — publish a schedule for the use of freight shipping agents, showing allowed loads for each line between junctions or important stations. Any load offered in excess of these allowed loads is either reloaded to give lower wheel loads, or sent by a slightly differing route. This means that for each line between such points there may be one or more structures the strength of which limits the safe load. In case the line has been in existence for some years it usually is the case that there are several such structures, or in case the line was built by promoters, as is often the case, all the structures are equally light. It may well be that they are as good as new, only weak. If the traffic on such line is not too heavy or if the line is not part of a main trunk line, it will manifestly not pay to rebuild one or all the bridges, but the loads will be limited. Of course there is also a similar schedule for operating and motive power officials, showing limits for locomotives.

If, on the other hand, a single bridge limits the traffic, it becomes purely an economic problem to work out the advantage to be gained by its replacement.

In case the completion of a new connecting line opens up a new trunk line, or even an alternative line to be used as a trunk line in case of wreck or emergency, it may be the wisest course to replace the many structures. It may happen not to be a bridge that limits the line, but a turntable at a critical point, an ash pit, a roundhouse, a station with covered train shed; any of these or other conditions may limit the weight or size of locomotives and render unwise, that is, uneconomical, the replacement of other structures, weak but sound and in good condition and sufficient for the traffic as limited.

On branch lines it is nearly always an economic problem and may be political as well.

Perhaps some much desired industry needs facilities for handling heavy loads.

The near expiration of a lease may render it very unprofitable to rebuild a structure, even at the alternative of excessive repair charges.

On main lines it is sometimes needful to run heavy trains for advertising purposes even at an economic loss. Many structures are rebuilt for this reason long before weaker structures on branch lines are even strengthened.

It will thus be seen that economic or business or even political considerations may take precedence of strictly engineering or constructive problems, in determining time of replacement of structures.

After replacement is determined upon there is still a chance for economic errors of design which will make trouble later. A line good for only say 120 000 lb., on account of structures in first-class condition but of weak design, would not be entitled to 200 000 lb. structures, unless the latter are to outlive the former, and unless the future cost of strengthening will considerably exceed the present cost, enough to pay the interest at least. A structure near the end of a weak division adjacent to one stronger may well be made equal to the stronger division. In any case the economic problem should be worked out.

Since beginning the above, a paper has been presented at the 1906 September meeting of the American Society of Civil Engineers and abstracted in *Engineering News*, August 23, in which the author, Mr. W. J. Watson, Bridge Engineer of the Osborn Engineering Company, covers similar ground to the above. An editorial in *Engineering News* in September also attacks the same problem. It will be seen that the present writer has ideas somewhat at variance with those expressed by Mr. Watson and the editor. This is, no doubt, partly due to a different set of conditions, and partly to the inevitable difference of opinion between different individuals. Where such differences exist the writer sees no occasion to change his former conclusions.

DISCUSSION.

Mr. J. Parker Snow (by letter). — The subject of the paper is one of vital interest and importance to all railroad men. Much has been written upon it, and it is one of the subjects now being particularly studied by a committee of the American Railway Engineering and Maintenance of Way Association.

In addition to the paper by Mr. Watson, cited by the author, the following may be named: A paper by A. J. Himes, in *Bulletin 80*, October, 1906, American Railway Engineering and Main-

tenance of Way Association, which contains references to several papers and articles besides that of Mr. Watson; a paper by Wm. Marriott on strengthening early iron bridges, and the Austrian Railway Ministerial Order of August 28, 1904, concerning new and old bridges, both of which are in *Bulletin 4*, April, 1906, vol. xx, of the International Railway Congress; and a paper by J. E. Greiner on the "Life of Iron Railroad Bridges" in Transactions American Society Civil Engineers, vol. xxxiv, page 294. A paper by Mr. C. D. Purdon in the JOURNAL OF ENGINEERING SOCIETIES, vol. xxxiii, page 325, gives a method of classifying locomotives as to their effect on bridges, together with a sample schedule of bridges, which shows at a glance the approximate maximum strain on every bridge under any locomotive that has been classified.

I agree entirely with the author that much depends on field examination in determining whether a bridge should be retained, strengthened or rebuilt for existing traffic. A table for each structure, showing the maximum unit strain in its various parts, should be in hand when such examinations are made. Rivets especially are to be judged almost wholly by their action in service. Much has been written about allowable shear and bearing strains, dependence upon friction, etc.; and, of course, high units are proper signals for examination, but if they keep tight they can be trusted. As the author says, they rarely fail by shear; they will show their weakness by becoming loose long before they will fail.

Timber bridges show distress much more plainly than those of metal, but the latter can be so examined as to show signs of weakness long before failure need be feared under existing traffic.

The principal difficulty that confronts an engineer responsible for bridges arises from the desire to increase the loading on old bridges. In this case he must judge what will be probably reasonably safe from the computed unit strains. He has much to guide him by a study of the structures that show weakness under existing loads, but no fixed rule can be assumed, because no two structures behave exactly alike. My experience has brought me to the conclusions expressed in this and the following paragraph. They are the basis of my practice in handling old bridges, but I should not wish others to follow these rules literally, because in every case judgment based on the action of the structure in question under load must temper the said rules. Pin trusses built 30 years ago will not bear the unit strains that riveted trusses of the same age will; and of the

latter, a pony truss will bear higher strains than a deep through truss. This latter is contrary to the teaching of many engineers, but experience proves it to my mind. Plate girders merit the confidence that all repose in them; but riveted pony trusses behave, with me, just as satisfactorily. The only way that I have known plate girders to fail has been by the top flange getting loose on the web in deck structures. This is due to wheel loads rather than to flange strain; they become loose near the center of span as generally as at the ends. The allowed unit strain may well be 25 per cent. higher in the one type of bridge named above than in the other. Within limits, also, quite short spans, say below 20 ft., may be allowed to carry higher strains than longer ones. This with loads figured as static. I realize that this is another case of heresy, but I am sure it is true. The reason may be that the frame of the engine assists the bridge, or that the running rail helps it out, but the fact remains that at 5 ft. any old stringer will do, even if it figures above the breaking strain.

Our author does not fix upon an allowable unit strain. It is delicate ground, but without some basis for discussion no definite result can be reached. The unit strain and the impact allowance, as it is generally called, are balanced factors, and no intelligent consideration of the matter can be reached without treating them simultaneously. Again, in making impact allowance, the question of speed must be taken into account. Ordinary railroad traffic at speeds below 20 miles per hr. may be considered as static. At 60 miles the allowable unit should be decreased 25 per cent. or the load increased 33 per cent., if a constant unit is used, on ordinary types of 100 ft. span and less. With these features in mind, the ordinary units used in designing may be doubled before a bridge need be condemned for high strains. This is a broad rule; its application needs to be varied to fit each individual case.

There is a wide difference of opinion among laymen, and quite a little among engineers, as to whether a bridge is suitable for given loads. This difference covers all the ground between not exceeding the load for which the bridge was designed and the idea that this load can be multiplied by the ratio of the ultimate strength to the unit strain used in the design (the so-called factor of safety) before the bridge will fail. Both these views are manifestly extreme. The first would seem to claim that if bridges will carry safely more load than that for which they were designed they are thereby proved to be un-

necessarily heavy. We sometimes hear it said that they are purposely made over-strong to provide for future increase of loads, but if we ask just how much overload is provided for the answer is indefinite. If we expect a certain overload we ought to take that load as our weight to start the design with. The fact is we do not design our structures to just carry the prescribed load with safety and not break down, but to carry it satisfactorily; and every increase of the prescribed load will decrease the satisfactory working of the bridge. The vibration and deflection will increase under increased loads and more frequent repairs will be called for until the load is such that the strains in first class riveted work are about twice what were used in the design, when the action of the bridge will generally become so unsatisfactory that its renewal will be welcomed by all. Multiplying the original load by the so-called factor of safety cannot be done on account of unequal distribution of strains, imperfect material and rough workmanship.

Of course deterioration is a live factor in condemning bridges. The author covers that feature fully. Modern structural steel corrodes with alarming rapidity. Why it should corrode so much faster than wrought iron is being studied by a Committee of the American Society for Testing Materials. The question of molecular change (crystallization) is not talked about so much now as formerly. If badly overstrained, say about three times the allowable unit, iron will get brittle; but most of the brittle material found accidentally in service was just as brittle when put in as when found.

The celebrated paper by Mr. Watson, referred to by the author, advocates the Pritchard formula for impact when investigating old structures. A comparison of this formula with others is given in the annual proceedings of the American Railway Engineering and Maintenance of Way Association, vol. vi (1905), page 257. That comparison shows that for ordinary tie-floor single-track railroad bridges there is but little difference in the final results between the Pritchard, the Schneider and the Cain formulas. For double-track trusses and floor beams the Schneider formula gives more reasonable results than the others, while for ballast floor bridges the opposite may be true.

These formulas were designed for use in proportioning new bridges and they provide very liberally for the impact of moving trains as well as for secondary strains due to non-symmetrical connections. If applied in analyzing old bridges a unit strain of at least 25 000 should be used and then many short bridges

will be ruled out that are entirely adequate for the desired service. It must be remembered that these formulas provide for speeds of 60 miles per hr. or over, and if slower speeds obtain, the impact addition may be less. I prefer computations on a static basis and unit strains varying from 15 000 to 20 000 according to judgment.

Timber stringers, if fairly sound, will not fail at 2 400 fiber strain. In tension or compression, however, timber will not generally safely carry this strain. In this case it becomes a matter of side support and end connections which in timber trusses are generally very faulty.

Concerning the deterioration of timber, the author's remarks accord with my experience. A feature not touched upon by him is the fact of greater durability of timber in cold climates than in warm. Altitude is equivalent to higher latitude in this respect; and the difference in the life of exposed timber is very marked between the latitudes of Boston and Montpelier, and between the altitude of Boston and Ashburnham, Mass. The difference in the life of Southern long leaf pine is fully three years at the points named.

Mr. Joseph R. Worcester (by letter). — Mr. Higgins has chosen a subject of great importance, and his treatment of the question is, in the main, entirely satisfactory. There are one or two points, however, upon which he is not quite so specific in his recommendations as might be desired.

He states that unit strains in metallic structures should never be allowed to reach the elastic limit of the metal. In this there can be no doubt that all engineers will agree, but are we to assume that, if the strains do not reach the elastic limit, he would pass the structure as safe? In other words, would he allow a tensile strain in a main member of steel of 30 000 lb. per sq. in.?

Mr. J. E. Greiner, assistant chief engineer of the Baltimore & Ohio R. R., in a discussion of the subject for the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, has recently presented a convincing argument against allowing any higher strains in old structures, in which there exist uncertainties as to the nature of material as well as perhaps imperfectly designed details, than would be allowed in new structures, properly designed and built of carefully inspected material. As against this, of course, we may say that in designing new structures we advisedly use lower strains than we know to be safe, for the very

purpose of providing for an unknown future increase of live load. It is, however, an illogical method of making this provision. When modern specifications are tending more and more toward the method of reducing all possible strains, including impact, to an equivalent static strain, and using for the unit strain a flat unit supposed to be correct for a static load, we should logically, if we want to provide for an increase in future loading, make the desired provision by an increase in the assumed live load.

The general practice at the present time, both for railway and highway bridges, as well as for other structures, is to use a unit strain of about one half the elastic limit of the material. This factor is considered correct in places where the load assumed is an absolute maximum, as, for instance, where it consists of a definitely determined dead load only. There is reason enough for allowing this factor on account of possible irregularity in the metal and internal stresses due to imperfection of details. Can it be said that these elements are less likely to be present in old structures than in new? Manifestly not.

The only excuse for allowing this factor to be reduced in an old structure would be that by careful watching it might be safe to rely upon distress becoming apparent before an accident could result. This would seem to be a doubtful dependence unless an almost daily careful inspection were made, which would be well-nigh impossible.

It is to be hoped that the author will give us more specifically his views upon this point.

The author tells us that the hammer is not a sure guide in the detection of overstrained rivets. The writer agrees so far as to admit that no examination of a structure without calculation of strains is as safe as careful analysis. At the same time the writer has always held the opinion that a rivet which was really tight under the hammer was doing its work, and that it would give evidence of weakness, by becoming loose, before it would fail. It is undoubtedly true that many rivets, if not all, do their work solely by clamping the parts together so strongly that motion is prevented by friction, even though the shank does not bear on either side. This condition is perfectly normal, and so long as the friction is sufficient, is ideal. The time will come, in the writer's opinion, when rivets will be figured by friction, which bears a constant relation to the shearing strength, rather than by bearing and shear, which never are called into play until the joint slips to some extent. Even

when the joint has slipped, and the bearing and shear come into action, if the rivet remains tight, it cannot have been seriously overstrained. If the author has seen cases where rivets ringing tight have failed in service, it would be instructive if he would describe the circumstances.

The author's fears with regard to the future of reinforced concrete bridges do not appear to be well-grounded if we may judge by analogy with reinforced concrete beams and slabs. In one respect, at least, there is an element of safety in all concrete structures not existing in stone and brick, that is, the growth in strength that occurs in this material with age. It seems probable that where the determining strain is pure compression, this increase in strength ought to go far towards taking care of the increase in live loads for a very considerable period. On the other hand, the addition of a tensile strength at the critical points of an arch, even though the exact amount or nature of the reinforcement is uncertain, should contribute a certain ductility above the elastic limit not possessed by *voussoir* masonry. It is well known that beams or slabs of reinforced concrete will often deflect to one thirtieth or one twentieth of their span before failure, while cracks may open almost enough to allow the reinforcement to be measured. These circumstances certainly ought not to be considered as adding anything to the hazard.

PROF. GEORGE F. SWAIN. — I have listened with much interest to the paper by Mr. Higgins and to the discussions which have been read by the secretary. They bring out many interesting points. My own feeling is that the inspection and replacing of old structures demand a very high degree of judgment and experience on the part of the engineer. His attitude of mind must be quite different from that of the designing engineer, who merely has a set of specifications to go by and makes his structure strong enough so that it will be sure to carry its load safely. The engineer who has to consider an old structure must be able to judge of the faults of the original design, to estimate their effect, to recognize signs of incipient failure and to judge of their seriousness; and it is frequently a matter of great importance to his company whether he is willing to allow a structure to remain or whether he condemns it. It is very easy to condemn a structure, but it sometimes difficult to recognize that it is safe in spite of defects or weakness. The opinion of the writer was asked not long ago with reference to the renewal of a large and important bridge. It was weak in some parts and much lighter than would be built at the present time, but the

writer satisfied himself that it was safe and reported to the company that it need not be renewed at the time when his opinion was asked. The money which would otherwise have been required for its reconstruction was used in a way where it was greatly needed and the bridge continued to carry its load until a later date, when it was found more convenient to renew it.

In judging of old structures, the engineer will be assisted by remembering two facts: First, that the engineer is aided by nature; and second, that many things help support a structure which are not allowed for in the usual computations.

With reference to the first of these, a structure will stand up if it is a physical possibility for it to do so; that is to say, if a condition of stress is possible which is consistent with the physical conditions and the conditions of equilibrium. The yielding of one piece will throw the stress elsewhere. Even the failure of a piece usually considered necessary does not always mean the destruction of the structure.

With reference to the second point: In short wooden stringer spans, for instance, while we consider the load to be carried by the stringers under the rails in reality there are, in addition, as a rule, guard timbers, two track rails, frequently two guard rails and frequently side stringers. Many short spans would stand with perfect safety if the stringers under the rails were entirely removed. Then, again, friction is an element which frequently helps. In wooden trusses it is often the factor which really causes the truss to stand up. In riveted structures the friction on the rivets, usually neglected, may be sufficient to carry the entire stress on the rivets. The writer does not, however, agree with Mr. Worcester in believing that it would be proper to allow for this friction, since it is an essentially uncertain quantity, while the strength of the rivet is a positive quantity. Again, we allow for the nominal diameter of the rivet while in reality the rivet is about $\frac{1}{8}$ in. larger. With a $\frac{7}{8}$-in. rivet, this alone gives an increase in strength of about 15 per cent. Another practice of many engineers in not allowing for the action of the web of a plate girder in carrying the moment is an incorrect assumption on the safe side, like many others frequently made. In all of these ways many structures are really much stronger than they are computed to be.

It has been the writer's practice to allow the stress in the main members of a structure, making in some cases some allowance for impact, to reach about three fourths of the elastic limit before considering the structure to have reached the danger line.

No definite rule, however, can be laid down, as varying circumstances must be taken into account.

The writer believes, in the case of steel structures, that the principal cause of renewals is defects in design and not overstraining of the main parts. The loads to be carried by railroad bridges have increased very much in the past 30 years and yet there are many well-designed railroad bridges built 30 years ago which are still in existence and carrying these increased loads with perfect safety. On the other hand, some structures 15 years old or less have had to be renewed on account of defects in design, although the increase in weight of rolling stock has been comparatively small. A great deal of money has been wasted for our railroad corporations by improper design.

Coming to specific defects, the writer would like to say a few words in favor of the reliability of hard pine as a structural material. He has always found that after some years' service hard pine looks much worse than it is. The sap decays, but the interior of the stick not more than ½ in. to 1 in. from the outside is generally perfectly sound. White pine, on the contrary, he has not infrequently found unreliable and subject to dry rot. Many, if not most, of the wooden trusses built 30 to 50 years ago, in this part of the country at least, were built of white pine. The writer remembers one occasion in which he discovered by the use of the auger that three out of four sticks in a lower chord of such a truss were mere shells. In the examination of wooden trusses he has found that while the auger is, of course, the most useful instrument, the sound under a hammer, and even the color of the wood, are sometimes valuable and reliable indications.

The writer knows of no reliable means of ascertaining whether the vertical members of a Howe truss are equally stressed, unless they happen to be of equal size and of the same free length, in which case the sound under the hammer will be a good indication. If the sizes of the bars in one member are different, or if they have not the same free length, the sound will, of course, be no indication at all. The writer believes that such bars are often very unequally stressed.

With reference to steel structures, the writer would refer to a few defects in design. One of these about which he has said a good deal in the past is found in riveted structures and consists in not bringing together the members at one joint so that the center of gravity lines intersect at a point, or as nearly so as practicable. The secondary stresses due to a violation of this rule are sometimes exceedingly large. Eccentric connections,

in which the center of gravity of the rivets which take the stress out of a piece does not lie in the center of gravity line of the piece, also cause large secondary stresses. Sometimes these may be computed in a simple way and with a fair degree of accuracy, and it is not uncommon to find designs in which the actual stress in some of the connections is three to five times that which is supposed to exist. Such cases have not been infrequent in the experience of the writer.

Another defect which the writer has met with is in proportioning the web of the plate girders too thin, due to an apparent failure to realize that the web acts as a column. In some plate girders a slight motion of the web may be discerned as the train passes over. The writer knows of many cases in which it has proved desirable to add stiffeners. A thin web, of course, is also objectionable in reducing the bearing value of the flange rivets, a matter which has been alluded to by Mr. Snow.

Another matter which the writer has frequently had occasion to observe has reference to the use of stiffeners under bracket angles in floor beams. The stringers which rest on these brackets deflect under the load, and the tendency is to concentrate the load which goes into the floor beams on the outer edge of the bracket angle. Unless properly stiffened or unless properly designed to resist this bending, such brackets are liable to fracture. This sometimes takes place at the inside of the horizontal leg and sometimes at the upper portion of the vertical leg. It is singular that so many brackets should have been used without any attention being paid to their design, and as a result the writer has found a number of instances in which such brackets have been broken. Professor McKibben will give the society some further details with reference to this.

I will only add that in the specifications of the railroad commissioners provision is made that such brackets shall be stiffened by angles beneath. If not so strengthened, a minimum thickness is prescribed, but stiffening is insisted upon wherever practicable.

Many other matters might be alluded to if time permitted, but I have already occupied too much of the time of the society.

Mr. Frank P. McKibben. — Mr. Higgins' interesting paper has touched upon many points which I hope will be fully discussed here to-night. The question of the distribution of loads upon highway bridges by the planking which forms the floors of such structures is one which is important not only in the study of existing bridges, but also in the design of new ones.

In the *design* of track stringers of highway bridges carrying electric cars, the stringers directly under the rails should be computed to carry the entire loads from the rails without relying upon the planking to distribute the loads to adjoining stringers. In the study of existing bridges of this kind it is frequently necessary, however, to assume that the planking distributes the track loads over a considerable width of the roadway and hence over several lines of stringers. If the planking is in good condition this assumption is allowable, but it is difficult or impossible to determine exactly how the loads are proportioned among the various stringers. A very common form of track construction is to have the rails resting directly upon a lower layer of planking, which, in turn, rests upon wooden stringers spaced $2\frac{1}{2}$ ft. on centers with one stringer directly under each of the rails. In this case the amount of load upon each of the stringers is far from equal. Given an electric car axle-load in the *center* of an ordinary 13-ft. panel, with 4-in. by 14-in. stringers spaced as just mentioned, the rail resting on a layer of continuous 4-in. planking, it can be shown that approximately 30 per cent. of the axle load is carried by each of the stringers under the rails, 26 per cent. by the stringer under the center of the track and 7 per cent. by each of the two stringers just outside of the rail stringers. These percentages change somewhat with changes in the size of stringers, thickness of planking, etc., but are of sufficient accuracy to show that the assumption of *equal* distribution is incorrect. As the weights of electric cars increase this becomes a matter of considerable importance.

An examination of existing highway bridges carrying electric railway cars reveals one form of construction which is so prevalent and so poor that it should be emphasized in order that existing bridges having this defect may be strengthened and that the evil may be avoided in future construction. The practice to which reference is made is that of supporting wooden stringers upon small steel shelf angles riveted to the webs of floor beams, the shelf angles not being braced by stiffeners fitted under the outstanding legs. It is not at all uncommon to find electric railway tracks on highway bridges carried upon stringers which rest upon shelf angles as small as 3 in. by 3 in. by $\frac{3}{8}$ in. Such angles are almost invariably overstressed, and the writer has in his possession *broken* shelf angles from three different bridges.

Let us assume the following case and investigate the shelf

angle. Panel length 13 ft., one stringer directly under each rail, each stringer supported at each end by one 3 in. by 3 in. by $\frac{3}{8}$ in. by 15-in. shelf angle riveted to the floor beam web, two wheel loads of 6 000 lb. each on a wheel base of $6\frac{1}{2}$ ft. These data give a maximum live end shear of 9 000 lb. on each stringer; say dead shear is 2 000 lb., total 11 000 lb. per stringer. The shelf angle must carry this and is subjected to a bending which is a maximum on horizontal sections just above the heads of the rivets which connect the shelf angle to the floor beam web. As the loads deflect the stringer the end shear of 11 000 lb. is at first thrown well out towards the outer edge of the horizontal leg of the shelf angle, but as this leg deflects under this load the resultant of the pressure acts nearer the vertical leg of the shelf angle. If the 11 000 lb. is assumed to be uniformly distributed over the outstanding leg, the maximum bending moment in the shelf angle is $11\,000 \times 1\frac{5}{16} = 14\,400$ in.-lb., and the maximum fiber stress in the angle is (neglecting a slight additional compression) $\frac{14\,400 \times 6}{15 \times \frac{3}{8} \times \frac{3}{8}} = 41\,000$ lb. per sq. in.

Of course as this angle receives this stress it bends downward and the stress is reduced, but that it is highly overstressed is obvious.

In many cases the shelf angle is made continuous along the floor beam instead of being used in short pieces under the stringers. This continuous angle is somewhat better than the series of short pieces, but unless made very thick is poor construction.

Stringers are frequently set directly on the top flange angles of floor beams without any stiffeners under them. This is also a poor form, since the outstanding leg of the top flange angle is subjected to a bending moment very similar to that already discussed. These top flange angles and the shelf angles should be provided with stiffeners properly fitted to the outstanding legs.

Mr. L. S. Cowles. — The author's idea of judging the fitness of an old bridge from a common-sense point of view rather than a too theoretical one seems to be the sanest method to pursue. However, the mere keeping of unit stresses below the elastic limit would hardly warrant a feeling of contentment for the inspecting engineer unless the stress were well below, or say under three quarters, of the elastic limit.

With regard to the indeterminate element of rivets in a structure, I feel that if a rivet is tight under the hammer test, it must be doing some of its intended work, even though it

does not fill the hole, or may otherwise lack the requirements of a so-called first-class rivet.

The most frequent overloading of city bridges seems to come from the ever-increasing weight of the electric car, whether urban or interurban. The main girders and trusses are no doubt less likely to be overstrained than the floor system, and especially the connections of stringers to floor beams. In old city bridges the practice of supporting wooden stringers carrying car tracks on single unsupported shelf angles is to be deplored, and all such defects should be remedied by means of vertical stiffeners under the outstanding leg of angle, or where there is not sufficient space the angle may be supported by vertical bolts and a yoke over the top chord of floor beam.

The question as to what constitutes a "liberal allowance" for impact for electric-car loading is a much mooted one. Mr. C. C. Schneider, in his very excellent paper on "Bridges for Electric Railways," *Street Railway Journal*, issue of September 22, 1906, introduces his impact formula for railroad bridges in a modified form, so that the addition for impact due to electric car loads is practically one half that due to locomotive loads. This seems perfectly safe, as the speed maintained on most electric railways is much lower than on trunk lines, and the rotating effects of the motors, is no doubt, less disastrous than the reciprocating motion of the steam locomotive parts. Certain defects common in the track system of many electric roads might tend to equal the pounding effect of poorly balanced locomotive driving wheels, but over such a roadbed high speeds could not with safety be maintained.

Referring to the ever-increasing electric car loads, it may be of interest to know that the heaviest surface car now being equipped on the Boston Elevated Railway system will weigh, when loaded, about 41 tons, and in case the motors are mounted on one truck only, the load on the motor truck will be about 25 tons, or practically the same as for an elevated car on the same system. It is thus seen that for short spans, such as stringers, this is equivalent to a 50-ton car, and in the light of present facts it would seem advisable to adopt as a standard a 50-ton electric car about 45 ft. long in designing new work where car tracks are to be supported.

Mr. Frederic H. Fay. — The speaker indorses, in the main, the author's views in regard to reinforced concrete arches and believes that his criticisms are applicable to reinforced concrete structures in general. While the strength of an existing

structure of wood or iron may be determined within reasonable limits from no other data than those obtained from a field examination, in the case of the structure of reinforced concrete, with the original records missing, it will be extremely difficult, if not impossible, to determine its strength by inspection. The increase in live loads should be taken into account when one is considering the question of building a bridge of steel or of reinforced concrete; and it should be remembered that while, in many cases, a steel structure can be built which will admit of future strengthening at slight expense, thereby prolonging its life, it is by no means a simple matter to strengthen a reinforced concrete structure. Because of this difficulty in strengthening, the uncertainties of workmanship and the practical impossibility of inspection in service without the original data, not to mention our present lack of knowledge of the behavior of reinforced concrete structures during a long term of years, the speaker believes that good designing calls for a considerably higher factor of safety in reinforced concrete structures than is used to-day in structures built of steel.

At the present time there is a remarkably rapid increase in live loads on highway bridges carrying street cars. In Boston, for example, a number of city bridges originally designed to carry a uniform live load of 100 lb. per sq. ft., or a single 20-ton wagon, are now being strengthened by the Boston Elevated Railway Company to take trolley cars weighing 50 tons.

Professor McKibben has shown some interesting examples of unstiffened shelf angles broken in service by excessive live loads. It will be noted that Professor McKibben's angles are short, and that in each instance they broke in the vertical leg near the root of the angle. The speaker has in mind some long, unstiffened, shelf angles which formerly carried the street railway track stringers on a bridge in Boston, and which broke in the horizontal (outstanding) leg. One of these broken angles is now in the city engineer's office. It is of wrought iron, 3 ft. long, with 3-in. vertical leg and 3½-in. outstanding leg, and an original thickness of ⅝ inch. The thickness had been reduced somewhat by rusting from locomotive gases. The break in the outstanding leg occurred near the root of the angle, this leg being sheared entirely off for a length of about 18 in., while cracks on the upper surface extended some distance beyond the ends of the break. It is believed that this break shows that in an unstiffened shelf angle the load from a stringer is not distributed over a considerable length of angle, — a point

which should be remembered in designing continuous shelf angles.

The speaker takes exception to the author's statements as to the advantages of a single layer of plank over two layers in the floors of highway bridges. Where one layer of floor planking is used it will usually be allowed to continue in service until it is worn nearly through or it actually breaks under some heavy load; in short, until it becomes dangerous. With two layers of plank, the lower layer should be designed for strength and the upper for wear; and even if the upper layer be worn entirely through, the strength of the lower planking remains to carry the load to the stringers. The author admits that on city bridges " the double plank is economical and safe, as the frequent renewals of wearing plank allow effective inspection." The speaker does *not* agree with the author's statement that on town and country bridges the lower layer of plank will rot out before the upper layer has become so unfit for service as to require renewal. The speaker is of the opinion that in all highway bridges with plank floor-surfacing, whether the bridges be for city or for country use, it is the better practice to use two layers of planking.

In the case of plank floor bridges over railroads, it is often desirable to provide floor planking which will require complete renewal at frequent intervals, for usually it is only when the planking is so renewed that the metal work beneath the floor is repainted. In such bridges it has been, for years, the practice of the city of Boston to use untreated spruce for the lower layer of planking as well as for the upper layer, in order that the lower planking would be renewed and the metal structure repainted with reasonable frequency.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk St., Boston, by May 15, 1907, for publication in a subsequent number of the JOURNAL.]

SOME ENGINEERING LESSONS OF THE SAN FRANCISCO DISASTER.

By J. L. Van Ornum, Member of the Engineers' Club of St. Louis.

[Read before the Club November 21, 1906.]

The modern city is the creation of commercial needs, and its location is fixed by commercial conditions. The duty of the structural engineer is to so plan all parts of the structure that it shall resist (1) with certainty all definite calls upon it; (2) with no serious injury all probable calls upon it; (3) and without destruction all those occasional visitations that human power can resist. Grouped under the first heading are the live-load, dead-load and the ordinary wind-load requirements, etc.; under the second heading would be grouped such occasional attacks as those of fire, gales and moderate earthquakes in earthquake regions; under the third head occur such disasters as hurricanes and tornadoes, general conflagrations and severe earthquakes, such as at times appall humanity in disasters that are made possible by reason of inadequate design or construction (or both), permitted in order to save a small percentage of expense, but thereby hazarding the integrity of all, with the gambler's chance of some gain or great loss.

Successful resistance to earthquakes, even when severe, is possible; but as this concerns most cities only remotely, it will be passed over with the statement that unified foundations structurally carried to solid material, with a thorough sway-bracing of the frame, will preserve the integrity of a steel building in any probable earthquake; even in masonry walls, bands of metal reduce to small proportions the damage to them from seismic disturbances. It is mainly with the fire lessons that we are concerned, because they are of universal interest and application. It is true that, often when discussing these lessons, we hear the remark that the Baltimore and other fires teach the same facts; but if we analyze more deeply, we must conclude that the San Francisco lessons are unique in giving us generally the effects of fire only, while nearly all others have left the added destructive action of water and steam upon the highly heated fire-resisting materials.

The main study, then, will be that of different engineering materials with regard to their earthquake-resisting and fire-

resisting properties. In view of the general conditions found to exist in San Francisco, as developed by his careful inspection of the city, the writer would impress with all the earnestness at his command the absolute necessity that good construction must follow a good design, or the result is a failure. Faulty design may be partly or wholly redeemed by excellent construction, but a thoroughly good design may easily be utterly ruined by defective construction. These facts are not at all new, but they are so evidently often obscured or ignored that it would be well if they might be impressed with all the vividness of a new thing. The engineer should always see to it that his design is constructed of adequately good materials and executed with the necessary skill and character of workmanship.

Passing the discussion of foundations (not because they are less important than any, but because the superstructure is most exposed to the destructive agencies under discussion), it may be said that wood resists earthquake vibrations well if the frame and roof are properly tied and braced; the almost universal practice is to ignore such bracing, and then the result is a collapse. In fire, wood, of course, "adds fuel to the flames." Masonry walls of all kinds resist the earthquake usually without destruction if well built, generally with considerable damage; the effectiveness of resistance is enormously increased with but little extra expense by improving the weak part of the wall — the mortar — by putting into the mortar a large proportion of Portland cement *; and a further effectiveness of resistance may be secured by metal ties and bands. Against fire, even without the rupturing and exploding action of water from the fire streams striking the highly heated materials, stone of practically all varieties spalled and disintegrated badly and in varying degrees, enough to require its replacing for the sake of appearance even when it was not structurally incapacitated.

In buildings in which steel enters as an essential structural element, more attention must be given to lateral bracing and to connections to make the structure safely resistant to earthquake vibrations. A more definite lateral stability must be furnished, with less reliance upon the indefinite internal rigidity of the finished structure.

In fire, the particularly vulnerable point of buildings of the first class remains the inadequate protection usually made

* The Appraisers' building, which survived without a crack, was built with brick laid in cement mortar, and is said to have had a monolithic concrete foundation 6 ft. thick capping the foundation piles.

against the introduction of fire from the outside, through windows, doors and inadequately designed roofs which quickly burned away. The protecting effect of metal shutters and metal covering of window trim was great, increasingly so as its character was better, and often so decisively effective as to permit the saving of the building at critical times, as the Kohl building. Even without such protection the decided advantage of wire glass was shown in a number of cases, as that of the Western Electric Company's building. Although the heat shatters the glass, the wire holds the pieces in place in most instances, so that the flame cannot enter; and although it has the defect of diathermancy, even a weak defense inside may overcome the danger arising from the transmitted heat. It has become evident that, in general conflagrations, fireproof buildings are the innocent victims of outside attack rather than the cause. The conclusion is then inevitable that a very great need in improving conditions is adequate protection of exterior openings.

Passing without comment some of the lessons driven home by resulting failures, such as the necessity of adequate and correct connections, thoroughly good riveting, good bond between facing and backing, properly constructed partitions, etc., the general fact is noted (as may be readily seen from the views already shown) that terra cotta offers much less effective resistance to fire than does reinforced concrete. I can tarry on this lesson only long enough to state that this reference is, of course, only to good materials, well fabricated; and in this connection it should also be stated that critical examinations have indicated grave danger of the gradual scattering corrosion of metal embedded in cinder concrete.

There probably is no more important or instructive lesson to be drawn from this disaster than the imperative necessity of adequate protection of essential metal, whether this metal be a steel frame or steel reinforcement of concrete construction; and a considerable advance has been made in determining with much greater definiteness the details of such requirements. San Francisco's revised building laws, as approved on July 5, 1906, permit of the use of brick, metal lath and plaster, terra cotta and concrete. Brick of proper quality furnishes good protection if the minimum covering of the most exposed metal is at least 4 in., and the mortar is of Portland cement. Metal lath and plaster may, with care, be made efficient, but the wisdom of its permissive use seems to the writer to be doubtful, because the requirements for efficient resistance are so easily

slighted; the fact remains that a noticeable proportion of failures in San Francisco were due to a sham application of this kind of protection.

When terra cotta is used, the minimum protection should be at least 2 in. for beams and girders and 4 in. for columns, with especial attention given to proper mortar and to metal ties. It must also be remembered that, where the heat is great, the outer web of terra cotta blocks shears off and falls, due to the excessive differential expansion of this outside web even when water from fire streams does not add its rupturing effects by cooling suddenly the highly heated surfaces; this usually means the preservation of the integrity of the steel frame, but does necessitate an entire reconstruction and replacement of the ruptured terra cotta.

Concrete or reinforced concrete of good quality both protected the structural metal and usually avoided the necessity of reconstruction (because the injury to it was superficial, not radical), except when the thickness of this protection was insufficient. In cases where the embedded, protected steel reached within an inch or so of the surface, the fire conditions often ruptured off the thin protecting layer of concrete, leaving the steel exposed. This is especially liable to occur on the under side of floor-beams and girders, where the embedded rods are so near the surface that the highly heated covering differentially expands considerably as compared with the concrete above the steel, leaving an easily ruptured section in the plane of the reinforcement where the bars are so numerous as to greatly reduce the area between them of the concrete connecting this outer protecting layer with the mass of concrete above the reinforcing steel.

It is believed that 3 or 4 in. of covering for the metal is as necessary for reinforced concrete construction as for column coverings of brick or terra cotta in order to give columns adequate fire protection. Tending to confirm this opinion is the fact that as a general proposition, in a temperature of 1200 to 1500 degrees fahr., heat will penetrate concrete to a depth of 2 in., enough to raise its temperature to 500 degrees fahr. in less than an hour, while it takes perhaps three hours for this temperature to penetrate 4 in.; this is significant because noticeable loss in strength occurs at about this temperature, which increases rapidly for higher temperatures. For evident reasons the regulation of the item just mentioned must be covered by the building laws of cities in order that it may be made

effective, as in the case of so many general requirements necessary for the public safety and welfare.

Hitherto it has been considered that a point of especial vulnerability is the lower flanges of beams and girders. While this fact essentially remains true, it seems that, relatively, more attention must be given to the adequate protection of columns, inasmuch as the failure of one of the lower columns involves not only the loss of it, but also the letting down or destruction of everything above it. The most prevailing cause of destruction and loss in the San Francisco fire, caused by a single class of weakness developing, was due to the partial or complete failure of basement or lower story columns exposed to the fire by the destruction of their fireproofing.

I would add, in closing, one reference that concerns engineering in its commercial and business relations. The adequate protection of essential members from fire will add a small per cent. to the cost of a building over its cost if partially protected. This amounts to a few thousand dollars, which looks large to the firm paying for the structure; consequently, as a rule, the firm will take the risk of destruction for the sake of saving this extra initial expense. Were the small additional expense of thorough fireproofing assumed, it would not only decrease the hazard to the owner, but would make the structure a safer risk to insurance companies. Unfortunately fire insurance companies will not make public such statistics as they have, giving relative losses on different types of buildings. Yet it is believed that their relative losses on buildings of the first class are much less, proportionally, than is indicated by the somewhat lower insurance rate now prevailing for such buildings. In other words, the reduced hazard secured by thorough fireproofing and fire protection ought to secure to the owner an insurance rate so noticeably lower that this saving would go far toward compensating him for the extra expense in securing this increased safety. This reduction in rates might well be made still greater when fireproofed buildings are compactly grouped, thus mutually protecting one another. Engineers, architects, insurance men and men of business would probably find that united consideration of this subject would lead to a mutually beneficial adjustment of these interests on the lines indicated.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by May 15, 1907, for publication in a subsequent number of the JOURNAL.]

THE CONCRETE BLOCK AND ITS ADVANCE TO THE POSITION OF A FIRST-CLASS BUILDING MATERIAL.

By Clarence M. Barber, Member of the Detroit Engineering Society.

[Read before the Society November 30, 1906.]

Concrete was used in important engineering work many years before it rose much above the subaqueous foundations of heavy bridge piers, or the footing courses of masonry structures. Gradually it ascended from this lowest position among structural material. Instead of the bottom course, down deep in the earth, it displaced the heavy dimension stone and took its place as the proper material for bridge piers and retaining walls.

Very slowly, indeed, reinforced concrete came to the front. It was some time before the engineering profession realized how admirably concrete and steel mutually reinforced each other when properly proportioned in a beam or column. Of course, proper engineering data were not at hand. Gradually, little by little, these were supplied; then, aided by steel reinforcement, concrete, rising above the pier and abutment, boldly spanned the openings between them and took a new place in the confidence of the whole engineering profession.

The properties of cement were studied by the most noted engineers, and it was soon utilized in almost every kind of static construction. At the present time reinforced concrete construction is going forward at a rate that is marvelous.

The structures that are growing into being every hour, that are rising high above the older buildings, many of them with imposing grandeur, mark a change for the better in the construction of certain classes of buildings that very few of us can realize. Rapidity of construction, moderate cost, strength and durability alone would win, but we must add the fact that concrete is the only building material that successfully stands up in a great conflagration.

Reinforced concrete is peculiarly adapted to the construction of beams, columns and floors. It is sometimes used for walls, but more often the continuity of the structure is broken by the use of other material.

The concrete block is a form of this material adapted to the construction of walls. From the earliest history walls have been

built of blocks of hewn stone or molded from clay. The outward appearance of the wall and the comfort of the dwellers inside have always been characteristic of the material of which the wall was made.

Concrete building blocks have been made and successfully used long enough now to develop their strong and weak points, and to supply some useful and reliable data. Their use has extended so rapidly that they are now in contact with conditions that demand improved quality.

Concrete blocks were invented in a crude way many years ago. But it was necessary for them to come somewhat into use before the conditions which had to be met were known and the defects could be corrected.

The advantages of a hollow block wall were at once recognized as an advance over the solid brick or stone walls in use. The fact that concrete ordinarily absorbs water as readily as brick induced a number of inventions which were designed to prevent dampness from percolating from the outer to the inner face of the wall. Some of these were quite effective. In nearly every block now on the market the matter of preventing water from reaching the inner face of the wall has been considered. In quite a number the inside face of the wall is more or less separated from the outer face. This is notably so in what is known as the two-block systems, where the outside and inside of the wall are composed of two separate blocks. These generally are of the L, T or triangle shapes, which bond with each other on their horizontal joints. In one case the two blocks forming the inside and outside are entirely separated except for small bent anchor bars built into the blocks, holding them apart. In another case a stratum of waterproof compound of a coal tar or asphaltum nature in the middle of the block hygrometrically insulates the inside half of the block from the outside. Several of these accomplish the purpose intended, viz., the preventing of moisture absorbed into the outer face of the block from passing through and appearing as dampness on the inner face. Of course where furring and lath are used the moisture absorbed by the block, which is no more than is usually the case with brick or stone, will not cause the plastered wall to be damp.

In all of the above, while the inner face of the wall is protected, which, of course, is extremely important, the outside face absorbs moisture from rainstorms, and being of a color which shows dampness, it often presents a disfigured appearance after a prolonged rain.

Concrete can be made practically waterproof by making the aggregate as dense as practicable and using about one half as much cement as sand. It is also claimed that a little thoroughly hydrated lime is an advantage. In the case of blocks, however, the quantity of cement required for a 2 to 1 mixture in the body of the block is generally prohibitive on account of its cost.

The most recent and, we believe, the best method is to make the body of the block of a good strong concrete with properly graduated sizes of pebbles or broken stone and sand, together with cement enough to make a thoroughly strong concrete and then face the block with a thoroughly dense and waterproof mixture made by using 1 to 2 cement and sand and 1 per cent. of a good waterproof compound. This protects not only the inside face but the entire block, and practically no moisture is absorbed even by the outer face.

A glass of water inverted on the smooth face of a block will hold the water for weeks with practically no absorption by the block. The writer has had a glass of water inverted on a piece of a block that stood on his mantel 40 days. At the end of this time the water escaped, due almost entirely to the expansion and contraction of the air in the glass above the water from changes in temperature.

Within the past year the tamping of concrete blocks by the pneumatic hammer has been introduced in many large block factories. As the material is thrown into the molds, it is hammered home by a shower of 500 blows per min. from a rammer driven by compressed air about 100 lb. per sq. in. This gives a greater density to the concrete than is possible by any other method of ramming, and makes it more homogeneous.

Some of the advantages claimed for concrete walls are as follows:

A dry, hollow wall, which is certainly the most desirable for all kinds of habitable buildings.

The outer face of the concrete blocks can be made in desirable architectural designs of greater variety and at less expense than any other building material.

It requires no paint and never decays or becomes unsanitary.

It resists fire better than any other known building material

It is cheaper than any other material of its class.

It has been argued that a perfectly waterproof wall would not make as desirable a dwelling as one that is more porous and will permit the diffusion of air through the wall. The hollow spaces in a properly constructed concrete wall are connected

both horizontally and vertically, and in dwellings this inner space is ventilated by a few openings in the basement and attic, so that while the outer face of the wall protects it from moisture from without, the inner face being more or less porous, permits diffusion into the interior, thus giving the advantage of a porous wall as far as the inside is concerned.

In the manufacture of concrete water plays an important part. The amount required varies from about 9 to as high as about 18 per cent. In the setting of concrete the water enters into chemical combination with the other elements, forming, according to Le Chantelier, crystalline calcium hydrate and hydrated monosilicate.

It is convenient and, we believe, consistent with well-founded theory to consider the combined water as the water of crystallization. Following this theory we may think of the setting as the forming of crystals and think of the particles of cement as throwing out acicular arms in every direction, which interlock and hold fast to each other. According to this theory, then, the setting and hardening of cement is not a drying process, but a crystallization. When all of the water required for the complete crystallization and no more is present it will be all taken up and the concrete will be dry. If the water required to complete the crystallization is not all present the formation of crystals will be arrested before they are fully developed. Then if water be again supplied, the final setting will not be the same as if the setting had not been interrupted.

It is extremely important to the proper setting of concrete, if the best results are to be obtained, that it be protected while the process is going on from the wind and sun, especially in dry, warm weather. The dry air will rob the sharp corners and even the faces of their moisture, and a later wetting will not repair the damage.

In a well-equipped concrete block factory, the freshly made blocks are kept for a time in rooms where the atmosphere is saturated with moisture, and generally a sufficient quantity of steam is admitted to hold the moisture above the dew point. This treatment gives sharp, hard corners and edges to the blocks; and, together with a little heat, it hastens the setting.

As to fire-resisting properties. When concrete, which has been fully set, is heated to the boiling point of water, the water of crystallization will not vaporize. It must be heated to about 500 degrees before the water begins to come off, and dehydration is not complete until 900 degrees fahr. is reached. Mr. Spencer

B. Newberry, who is probably one of the best authorities on the subject, states that cement concrete derives its capacity to resist fire from its combined water and porosity. He gives 18 per cent. of the cement contained for the amount of water which a mixture of cement with three parts of sand will take up. The vaporization of the water absorbs heat and keeps the mass for a long time at comparatively low temperature. The porosity of concrete also gives great resistance to the passage of heat. In a fire the outside of the concrete may reach a high temperature; the heat only slowly and imperfectly penetrates the mass. Professor Norton, in his report on the Baltimore fire to the Insurance Experiment Station, says:

"Where concrete floors, arches and concrete steel construction received the full force of the fire, it appears to have stood well, distinctly better than the terra cotta." Again, the same author says:

"When brick or terra cotta are heated no chemical action takes place, but when concrete is carried up to about 1000 fahr., its surface becomes decomposed, dehydration occurs and water is driven off. It would take about as much heat to drive the water out of this outer 0.25 in. of concrete partition as it would to raise that 0.25 in. to 1000 degrees fahr. Now, a second action begins. After dehydration the concrete is much improved as a non-conductor and yet through this layer of non-conducting material must pass all the heat to dehydrate and raise the temperature of the layer below, a process that cannot proceed with great speed."

In the coloring of blocks some very good and acceptable work has been done, but as far as our observation goes coloring has not been entirely satisfactory. Colors with the ordinary pigments seem to fade in almost every case. The effect of the cement is a matter to be considered. It was a surprise to the writer to see in a block factory which he visited at Cleveland a beautiful brown stone and to be told that another near it of a different shade was colored precisely the same and that the difference was simply a question of a few months of age. Of course there are plenty of materials that can be safely used to color the faces of blocks, but they are to be selected with the greatest care. Mr. P. B. Beery, in the *Engineering News*, says that coloring should in all cases be made from the best metallic oxides, free from sulphur. As a matter of fact, blocks can and will be successfully colored, but the problem is not as simple as it at first appears.

One of the difficulties that has caused some embarrassment to block makers in the past has been that it was not easy in every case to produce fractional and unusual sizes of blocks. This has been in a great measure, if not entirely, overcome by the improvements on the block machines. The variety of blocks that can be produced and the flexibility of machines have been greatly increased. As the concrete block takes a more advanced position and better and more complete drawings are used, there should be no more trouble in this kind of construction than in any other. In fact, special blocks can generally be produced as quickly as they are required.

Concrete blocks were used first for foundations and basement walls, but like other forms of concrete construction, they quickly advanced to the superstructures, and to-day we see concrete block buildings going up in our large cities, practically all over the United States. In its progressive movement the concrete block has already gone beyond the cottage and smaller residence buildings and extended to churches, large apartment houses, banks and business buildings.

The concrete block has not yet reached the highest degree of its development, but it has progressed far enough, we think, to demonstrate that its use will continue to extend and the prominence which it has already attained will gain for it still more confidence among the best engineers and architects, and that it will hold a still more advanced position as a first-class building material.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by May 15, 1907, for publication in a subsequent number of the JOURNAL.]

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVIII. APRIL, 1907. NO. 4.

ANNUAL ADDRESS.

BY BERTRAM H. DUNSHEE, PRESIDENT OF THE MONTANA SOCIETY OF ENGINEERS.

[Read before the Society at Butte, Mont., January 12, 1906.]

TO THE MEMBERS OF THE MONTANA SOCIETY OF ENGINEERS:

Gentlemen, — Another year has rolled around since our last annual meeting and a new year sits upon the throne. How often have we spoken of that last year's gathering at Lewistown. We were royally received and entertained by the citizens of that flourishing city, and Kendall and Gilt Edge as well. Every member of the society who was fortunate enough to be present looks back with pleasure to the three days we spent in Fergus County.

It is a pleasure to look back over the year just passed and to see how much has been accomplished in our own State of Montana by the members of this society. The civil, mining, mechanical, metallurgical, electrical and hydraulic engineers have one and all taken an active and important part in the advancement and development of our great state.

The society has not escaped the Grim Reaper. During the past year death has claimed three members of our society. We have been called on to mourn the loss of Mr. Thomas T. Baker, one of the old-time members of the society, and one of the pioneers in engineering work in Montana; Mr. George H. Robinson, also one of the older members of the society, a mining engineer of large experience, both well and favorably known; and Mr. Charles W. Leimer, one of our younger members, a man devoted to his profession of mining engineering.

The year 1906 has taken wonderful strides in all branches of engineering work. The forces of nature have yielded more and more to the engineer as he has delved more deeply into her secrets. All over the world are seen large enterprises under the management of engineers, and certainly Montana is not behind in the general advance. New ideas and devices have passed through the trying experimental stages and have been incorporated in the general scheme for improvements in mining, metallurgy and other engineering branches. It is my intention in this paper to mention some of these improvements, more especially in mining and treatment of ores.

Perhaps the most far-reaching enterprise in the state is that of irrigation by the Reclamation Service under the Department of the Interior. Four irrigation projects are under way in Montana.

Milk River Project.

Preliminary work has begun on this project. Surveys have been made, office buildings erected and right of way for canals cleared. This project will ultimately reclaim 175 000 acres at an estimated cost of $4 500 000.

Huntley Project.

This project contemplates the reclamation of 33 000 acres of land located along the Yellowstone River in southeastern Montana, within the ceded portion of the Crow Indian Reservation, between Huntley and Bull Mountain Station. The lands reclaimed are along the Northern Pacific and Chicago, Burlington & Quincy railroads. They form a portion of the area which the Crow Indians, by treaty ratified by Act of Congress, approved April 27, 1904, ceded to the United States. Upon completion of allotments to the Indians, as required by the act, the area remaining is to be subject to disposition in accordance with the provisions of the homestead laws and the rules and regulations governing the disposal of public lands. The President of the United States will issue a proclamation giving notice when the lands will be thrown open to general entry.

Surveys have been made to outline a comprehensive system of irrigation for a portion of these lands, which will necessitate the construction of a main canal 40 miles in length. Contracts have been awarded for the construction of divisions 1, 2 and 3 of the main canal, for the necessary structures on the canal for distributing system of laterals and for a telephone system.

In addition to the cost of reclamation, the price of the lands is to be $4 an acre when entered under the homestead laws.

This project is about 60 per cent. completed, and it is expected that some water will be delivered to lands under it in the present year. The cost will be about $900 000.

Sun River Project.

This project was formally approved by the Secretary of the Interior on March 9, 1906, and the sum of $500 000 was allotted for initiating work of construction. The preliminary investigations indicate that in the valley of the Sun River, 256 000 acres are reclaimable, a large percentage of which is public domain. The irrigable area is a broad prairie extending from the Teton River on the north to Sun River on the south, a distance of 30 miles, and from the Rocky Mountains on the west to the Missouri River on the east, a distance of 70 miles.

The land, although extremely rich in all the elements of fertility, without water is only fit for grazing, but when irrigated will be very productive. The examinations made by the engineers show that this project is free from difficult engineering features, and the topography of the country is such that it can be built a unit at a time. It is possible that the first unit selected for construction will be the reclamation of about 16 000 acres.

The Lower Yellowstone Project.

This project contemplates the diversion of the waters of the Yellowstone River, — at a point 17 miles northeast of Glendive, for the irrigation of 66 000 acres of land lying in northeastern Montana and northwestern North Dakota.

The public lands available for homestead entry should, at the proper time, be filed upon through the land office situated at Miles City. The lands to be affected by this system are tributary to the Northern Pacific Railway line, which passes through Glendive, 19 miles from the head gates, and the Great Northern Railroad, which has a station at Buford, 2 miles from the lower end of the project. The probable size for farms on this project will be 80-acre tracts.

Work is in progress on the main canal and lateral system.

This project is well under way and water will be delivered under it in 1908.

When these four projects are completed it is estimated that they will cost over $13 000 000, and that about 500 000 acres will be reclaimed.

Railroads.

The Chicago, Milwaukee & St. Paul Railway Company has done an immense amount of grading and preparatory work on its road through Montana to the Pacific coast. The company is not inclined to give out any definite information, but from various sources, including statements in the newspapers, which are credited as coming from the president of the company, we are able to get a general idea of where the road will be located.

Roughly speaking, it parallels the Northern Pacific Railroad, although in some parts of the state, as in the eastern part, there is considerable distance between them, but in other places they run together for long distances and cross each other numerous times.

The St. Paul Railway enters Montana 25 miles north of the South Dakota line and extends in a northwesterly direction to Fallon. It crosses the Yellowstone River at Terry; then follows up the Yellowstone to Miles City, and from that place to Forsyth, where it leaves the river and goes in a northwesterly direction, crossing the divide between the Yellowstone and Musselshell rivers. It follows up the Musselshell to Harlowtown, where connection will be made with the Montana. From Harlowtown it goes over the divide to Sixteen Mile Creek and thence to Lombard. At Lombard the Northern Pacific Railroad will be crossed overhead and the Missouri River by a six-span bridge 600 ft. long, and the Missouri River followed to the Jefferson; thence the Jefferson to Whitehall. At Whitehall the road crosses the Continental Divide by way of Pipestone Pass to Butte at a maximum elevation of 6 350 ft.

A large force of men is at present at work on the divide between Whitehall and Butte. Two tunnels aggregating about 3 700 ft. will be driven and several high steel trestles will be made use of in this part of the work.

West of Butte the road follows the Deer Lodge, Hell Gate, Missoula and St. Regis rivers to a point near Saltese, where the ascent of the Bitter Root Mountains begins.

The company promises to have trains running into Butte by January 1, 1908.

Northern Pacific Railway Company. — Mr. F. J. Taylor, division engineer, states that there was no new work built during the year, the main work being improvements and betterments of the main line. There is under construction at present 12 miles of double track running west from Livingston, and a contract has just been let for constructing 75 miles of second

track between Garrison and Missoula, and work on same is just being started. On both of these lines considerable divergence from the present line has been made for improving the alignment and grade.

Oregon Short Line Railroad Company. — Mr. Wm. Ashton writes there has been no railroad construction in Montana during the year 1906. The survey of the Yellowstone Park Railroad enters Montana from Idaho over Ray's Pass; the distance from Ray's Pass to the proposed terminus of this line on the boundary of the Yellowstone National Park is 20 miles. This line of railroad is under construction south of Ray's Pass, and it is now expected that construction between Ray's Pass and Yellowstone Park will be completed early next season.

STATEMENT OF ENGINEERING AND IMPROVEMENT WORK CARRIED OUT ON GREAT NORTHERN RAILWAY AND OPERATED LINES IN THE STATE OF MONTANA DURING 1906.

Mr. J. C. Patterson, assistant chief engineer, writes that the improvement work on existing lines during the year was perhaps not of the magnitude of previous years, but at the same time there was a general advance in the condition of the railway, and a large amount of engineering work has been performed and is still in progress, looking to improvements in the future, especially in the way of reduction of the present rates of grade and revisions of location.

There were 67 miles of track extending east from Havre on the main line relaid during the season with 85-lb. steel rail, using Wolhaupter joints and tie plates, this replacing rail of a lighter section. In this territory the old main line switches were replaced with others of an improved pattern, and the work in general carried out with a view to caring for an increased traffic and the handling of heavier equipment.

In the way of replacing timber bridges with permanent structures, the most important work was the erection of a new steel bridge over the Missouri River at Great Falls, which work was successfully completed during the year. This structure is of a total length of 1 044 ft., composed of steel deck girders, 13 spans 80 ft. long and one 40 ft. It is supported by 13 piers and 2 abutments, founded on bed rock and composed of first-class masonry to the amount of 1 250 cu. yd. of sandstone secured from quarries adjacent to Great Falls. There are 550 tons of steel in the structure. To avoid interference with traffic the new bridge was erected on a line parallel to the original

track, on the upper side of the old bridge, so that the new structure was entirely completed and put in operation before any change was made in the old one.

Continuing the work of replacing timber bridges by permanent structures, work was started during the season on the Montana Central Railway of replacing with steel three crossings of the Prickley Pear Creek between Helena and Clancey, and three crossings of the Boulder River in the vicinity of Basin. The masonry work for these structures is sufficiently advanced to admit of the entire work being completed in the early spring, when some 600 lin. ft. of wooden bridges will be replaced by 437 lin. ft. of permanent steel structure.

To care for the demands of operation there were laid out and partially constructed during the year, within the limits of the state, 19 miles of additional passing tracks.

For the protection of traffic and safety of operation there was installed an electric staff system of block signalling at the Boulder Tunnel, and a further extension of this system between the terminals at Butte and the yard at Woodville is now being constructed.

Construction of New Lines.

The only work of this nature within the limits of the state has been expended upon the construction of the Billings & Northern Railroad, which is to connect the Neihart Branch of the Montana Central Railway at Armington, and the Northern Pacific and Burlington railways at a point on the line of the former about 11 miles west of Billings and 3 miles east of Laurel. The total length of the new line is 194 miles. The general course of the line from Armington is southeast, extending through the easterly portion of Cascade County and passing through portions of Fergus, Meagher and Yellowstone counties. The line, leaving the Belt Valley at Armington, follows up over the course of Otter Creek on an equated 1 per cent. grade; thence over an undulating country, crossing the divides or watersheds between Otter Creek and Arrow and Judith rivers, to the well-known pass between the Little Belt and Big Sandy mountains, commonly called the Judith Gap, at which point an elevation of 4 060 ft. above sea level is attained; thence gradually descending along the waters tributary to the Musselshell River, and thence over some intermediate divides down into the valley of the Yellowstone River at the point of connection with the Northern Pacific Railway. The maximum grade, other than that of the 12-mile

ascent up Otter Creek, is an equated 0.6 per cent. maximum curve, 4 degrees, of which, however, there is only one, the balance of the location being based upon the use of 3-degree curves or less. The limitations of grade and curvature imposed and the desire to obtain a thoroughly first-class line have led to the adoption of a line that will involve heavy construction expense. The estimated grading quantities will amount to 10 017 000 cu. yd., of which it is expected that 25 per cent. will be of higher classified material than earth. The total degrees of curvature is 6 202. The percentage of tangent or straight line to the total length of line is 73. There will be 4 tunnels of an aggregate length of 6 580 ft., the longest of which will be 2 400 feet, and the shortest 1 100 ft.

Considering the character of the topography and the large drainage areas passed over, the amount of temporary or timber bridging is comparatively small for the total length of line to be constructed. This condition has been partially brought about by the adoption of the plan to provide on the original construction as large an amount of permanent embankment as may be possible. The linear feet of bridging as now laid out is 19 600, requiring the placing of 500 000 ft., board measure, of timber. The longest bridge is at the crossing of the Musselshell River; this is to be 800 ft. in length, and provide not only for a crossing of the river, but also for an overhead crossing of the Pacific extension of the Chicago, Milwaukee & St. Paul Railway.

The work on the grading was started in June last, and up to date of November 30 there had been moved 3 396 000 cu. yd. of material — approximately 34 per cent. of the entire amount required. Great difficulty was encountered during the past season in the way of maintaining a suitable force, as on account of the large amount of improvement and construction work in progress throughout the country labor was very scarce and difficult to obtain. The maximum force employed at any one time during the past year was 1 500 men, 970 teams, 28 grading machines and 6 steam shovels. It is expected that a larger equipment will be employed during the coming season and the entire grading work completed, at least, by August 1.

The track will be laid from both ends of the line, with the use of 85-lb. steel rails in 33-ft. lengths, Wolhaupter joints and steel tie plates. The track will be fully ballasted and the line equipped with water supply, station and track department buildings, the right of way completely fenced and terminal facilities provided, the expectation being that the work will be

fully carried out and the line put in operation during the present year.

MINING.

During the past year mining has been unusually active and the mining engineer has been more than busy. The old companies have kept up to their record and many newly organized companies have added to the general development, especially of the Butte district. Numerous shafts have been started on more or less promising locations, and we all hope that they will all strike pay ore. The deeper mines have opened up still lower levels, and one shaft, the High Ore, is 2 600 ft. deep, with several other shafts not far behind. The various levels have been extended in all directions and numerous new connections made with adjoining mines, thus improving the ventilation of the mines and increasing the facilities for escape in case of accident.

I wish to testify to the care and accuracy of our mining engineers; they do not make mistakes. In all the many connections made between the mines belonging to the same company, or to different companies, I do not recall one where the error was of any magnitude, and generally there is no error.

As a matter of general information it may be interesting to know that the six companies comprising the Amalgamated Company have made an advancement of 22 miles in their drifts and cross-cuts during the year 1906.

The outlook for the future was never better for Butte from a mining standpoint. The lowest levels of our big mines show good values and large ore bodies.

This coming year still lower levels will be opened up and new ore bodies, or a continuation of the old ones, will be exploited. Thus do we add to our reserves by prospecting as we take from our reserves by stoping.

Butte's underground city is steadily growing; the streets and alleys, during the working hours, are sending a steady and ever-increasing stream of ore to the various shafts to be hoisted and shipped to the smelters where the yellow, white and red metals are extracted to add to the wealth of our great mining camp.

At several of the mines, notably the Mountain View and Leonard, larger engines have been installed, and skips have taken the place of cages to handle the increased tonnage.

At the Leonard Mine a new four-compartment shaft has been sunk and an up-to-date surface equipment installed. As it differs somewhat from others a short description may be interesting.

The structural steel head frame is now a part of the equipment of all modern hoisting plants in Butte and considerable improvement is noticeable in its construction. The steel skip bins and automatic dumping skips are among the first additions to this style of frame and the manner of dumping the skip shows decided improvement. Instead of a latch on the skip and a trip to dump it, a gap is cut in the steel guide wide enough to allow the shoes of the skip to pass through and the wheels of the skip to follow the curve into the bins, thus eliminating any danger of the skip dumping in the shaft and causing damage.

A decided departure from the older head frames in Butte is noticeable in the new steel head frame, much less material being used in its construction than formerly, and by this change of design a frame has been constructed equal in every particular to the others and at a large saving in cost, thus showing that we have been using altogether too much material in this class of construction. The general dimensions and a general description of this frame are as follows: Height of frame over all, 153 ft.; height from base to center of sheave, 141 ft.; distance from front to rear columns at base, 68 ft.; distance between columns (front and rear), 47 ft. 6 in.; its main members are constructed of two 12-in. 20.5-lb. channels and one cover plate $\frac{5}{16}$ in. by 16 in., the other side consisting of lattice straps riveted to the channels (the main members of older frames being constructed of two 15-in., channels 33 lb., and two cover plates, each $\frac{3}{8}$ in. by 20 in).

The main struts consist of two 15-in. channels with lattice iron straps riveted on the top and bottom sides; the braces consist of 8-in. and 10-in. channels and lattice iron straps; the gusset plates are only large enough to allow a proper connection of the members. The bottoms of the main members or posts are securely fastened to each other by struts connecting the front and rear columns, also struts connecting the front columns with each other and the rear columns with each other. These members are constructed of two 12-in. 20.5-lb. channels with lattice straps on the top and bottom sides. These members were omitted in the older steel frames, which has proved a serious defect where the ground around the shaft is moving. The bases have spread so far apart that the main rear columns have both been broken, as in the case of the old steel frame at the Leonard. In this case the anchor bolts on the front columns have been removed, allowing the ground to move without carrying the columns with it, and it would probably be a better plan to omit the anchor bolts on either the front or rear columns where there is any liability of the ground moving, as this would prevent the strain-

ing of the members as is so often the case at present. The material in the new frame is of the grade known as medium steel of a maximum ultimate strength of 68 000 lb. per sq. in. The weight of the frame and skip bins complete is 346 425 lb.

At the same mine, and forming part of the same equipment as the frame above mentioned, has been installed a cross-compound, double drum, first-motion, Corliss type hoisting engine, made by the Nordberg Manufacturing Company, Milwaukee, Wis. This engine is similar to the one at the Original Mine, with a few slight alterations, a better grade of steel being used in the drum, and the drum has also been ribbed, thus strengthening it considerably. The cylinders are 32 in. in diameter and the stroke is 72 in. It is capable of developing 3 000 h.p. With a load of 34 000 lb. (including the weight of the rope), at a steam pressure of 140 lb., it is good for a depth of 3 500 ft. The shaft is 18 in. in diameter; the main bearings are 18 in. by 27 in.; the crank pins are 9 in. by 7.5 in.; the cross-head pins are 6 in. by 9 in.; the drums are 12 ft. in diameter and 5 ft. 6 in. face, made of steel plate 1.125 in. thick, and will hold sufficient 1.5 in. round steel wire rope for a depth of 3 500 ft. Weight of engine complete is 500 000 lb.

As our mines get deeper the ore bodies are generally more distant from the hoisting shafts, and the tramming of the ore becomes a serious problem. For several years we have used many horses and mules in our mines and they have done good work and have lessened, very materially, the cost of tramming. But the horses or mules must give place to electricity. Electric power for haulage purposes was first used experimentally, but it has demonstrated many advantages over all existing haulage methods where the distance is considerable.

Electric locomotives are both durable and efficient, and as a means of conveying power to a distance electricity has many advantages over the other agencies used in tramming, both as to economy and flexibility. The electric locomotive, considered as a machine, has many points in its favor for mine use. It is simple in construction as well as in operation, and for hauling capacity it is by far the most compact of all forms of motive power. Externally the electric locomotive consists of a cast-iron box heavy and strong, nicely adapting it to the required service.

There is a similarity in the general design of the electric locomotives built by the principal manufacturers, the rated draw-bar pull and speed of the locomotive, together with its

weight, determining the normal capacity under ordinary circumstances on a level track in good condition.

The experience with electric locomotives in the Anaconda Company's mines has been very satisfactory. The company has for the past four years used at three of their mines electric locomotives for hauling the ore from the skip chute at the collar of the shaft to the main ore bins. The electric machines have proved themselves reliable under severe treatment.

The locomotives weigh 4.5 tons, have 30-in. gage, and 37-in. wheel-base, single-end control, two 12-h.p. motors, 1 200-lb. draw-bar pull at 500 volts direct current, and a speed of 6 miles per hr. By keeping extra repair parts in stock it requires but a short time to repair any breakdown that may occur. For the surface locomotives the common electric street car practice is followed in suspending the trolley with track return.

On the 2 000 ft. level of the Anaconda Mine there is an electric haulage system that has been in operation and working successfully for about 18 months. Two hundred and fifty volts, direct current, are used in the mine. This is not dangerous to one coming in contact with it. The tramming distance on this level is 1 700 ft. The trolley wire used is a No. 0 hard drawn copper suspended from one side of the cross-cut and is supported about every 30 ft. by clip hangers. These are secured by drilling holes in the back of the cross-cut, then driving wooden plugs in them, to which are fastened the trolley wire insulators. The feeder wire for this system is a No 2–10 copper stranded conductor, rubber covered and braided, with $\frac{3}{32}$-in. lead covering over all. The return for the circuit is made by using old discarded lighting wires and the main air pipe line. Twenty-five lb. rails are used and the track is bonded by using short pieces of No. 1 copper wire wedged into the holes drilled into the web of the rails, the bond wire being located along the outside of the rails beside the fish plates. At starting an extra heavy load there is about 5 per cent. drop in the line. At times some trouble is experienced by oil and wet ore accumulating on top of the rail, causing sparking at the wheels, due to poor electrical connection with the rails. The locomotives are given a thorough inspection about twice a month by an electrician, when the commutators and controller contacts are given a good cleaning.

We have two locomotives made by different firms; both have been given a good trial and both work satisfactorily on an 18-in. track. One locomotive has a 26-in. wheel-base, weighs

2.5 tons, with an 800-lb. draw-bar pull, one 15 h.p. motor connected with the other axle by a sprocket chain.

The other locomotive has a 34-in. wheel-base, weighs 3 tons, with a draw-bar pull of 700 lb. and two motors of 5 h.p. each, one over each axle. The speed of each locomotive is 6 miles per hr., which is certainly fast enough for any underground work in these mines.

The work done by these locomotives has been very satisfactory; they will push or pull a load and we find no difficulty in hauling 15 loaded cars (23 or 24 tons, including cars) on an up-grade. Our grade is generally 6 in. in 100 ft. Ten cars is about the average load, and these are easily handled.

We have not yet branched off from the main cross-cut, but this can be done at any time, and it will be done when the level is sufficiently opened up to make it necessary. The cost for power is small, probably in our mines here in Butte it is less than the amount necessary to keep two horses, and one locomotive will do the work of several horses; besides, in a case of a temporary shut down the expense ceases at once.

Electricity as a motive power for underground work in Butte mines is in its infancy, but this year will see a large increase in its use. The trolley line on the 2 000 level of the Anaconda Mine is the only one in operation underground in any of the Butte mines at present, but both the 1 600 level and the 2 200 level of the Anaconda Mine will have electric locomotives before long.

The Boston and Montana Company are preparing to install electric haulage systems on the 800, 1 100 and 1 400 levels of the Leonard Mine. Other companies will see the advantages of this power in underground work, and they will not be slow to make use of it. We shall have an underground trolley system that will rival the one on the surface.

Boston and Montana Consolidated Copper and Silver Mining Company. — At the Great Falls smelter, of which Mr. A. E. Wheeler is superintendent, no improvements of importance have been made this last year, but for the coming year very important changes have been decided upon.

The Boston and Montana Company decided last year to increase the capacity of the works at Great Falls from 3 000 tons of concentrating ore and 500 tons of smelting ore daily to 4 000 tons of concentrating and 700 tons smelting grades, representing an addition of one third to present capacity.

In order to provide for these enlargements it was first neces-

sary to make plans for more water power, and the company has in view the development of a sufficient amount of power from the falls below the works not only to provide for the requirements of the proposed additional machinery, but also to supply enough power from this source so that steam power will not be required in seasons of low water, it having been necessary for the last several years to develop 3 000 h.p. from steam boilers during several weeks of the summer and early fall.

One of the most important matters in connection with the increased capacity is the building of a new chimney and flues, the present arrangements in this respect being inadequate for the duty required of them; so the company decided to build a very large chimney which would not only provide for the new furnaces already authorized, but would be large enough for all possible future extensions of the works. A contract has recently been let for a chimney 506 ft. high. This chimney will be so placed that the actual height above the surface of the ground will be 500 ft., and the inside diameter at the top will be 50 ft., while at the bottom the outside diameter will be 75 ft. The main wall is 64 in. at the bottom and 18 in. at the top, and a sectional lining is one of the features of the chimney, this lining providing for expansions and contractions. The chimney when completed will weigh 16 600 tons, and will be built of special brick which the manufacturers call "radial or segmental." These brick are also perforated, thereby reducing their weight to a certain extent and providing for a better bond in the construction. A brick plant will be built near the proposed location of the chimney, and this will contain several kilns for the proper burning of the brick.

A flue about 1 700 or 1 800 ft. long and 48 ft. wide will connect the furnaces with the new chimney, and this flue will have an enlargement for about 350 ft. of its length where the flue dust will be collected. The width of this part of the flue will be 175 ft., and provision will have to be made under it for the removal of the dust. The walls of the flue will be built of brick, but it is not yet decided whether the perforated or common form will be used. The contract for the chimney has been let to the Alphons Custodis Chimney Construction Company of New York. This company has built a number of high chimneys in the United States as well as in foreign countries. The highest chimney in the United States at present was built by the Custodis Company for the Offorx Copper Company, at Constable Hook, N. J. This chimney is 365 ft. high and 13 ft. in diameter.

Another large chimney built by this company, 300 ft. by 30 ft., is the one at the Garfield plant of the American Smelting & Refining Company in Utah.

The present chimney, which was built in 1890, has a height of 185 ft. and is 20 ft. in diameter, so the top of the new chimney will be 320 ft. above the top of the present one.

In this connection it will be of interest to compare the new chimney with the one at the Anaconda works. The chimney at Anaconda has a height of 300 ft. and a diameter of 30 ft., with a lining extending to a height of 145 ft. from the base. About 2 200 000 common brick were used in the construction of this chimney, while 5 700 000 common brick would be required to occupy the same volume as the walls of the proposed new chimney at Great Falls when built of radial brick. The top of the Anaconda chimney is 724 ft. above the blast-furnace charging floor, and the top of the new chimney at Great Falls will be 742 ft. above the blast furnaces, thereby giving a slightly better draft than is obtained at Anaconda.

The addition to the concentrating facilities at Great Falls, as stated above, will provide for the treatment of 1 000 tons daily, and experiments are now in progress which will probably lead to the introduction of improvements over old methods now in use at Great Falls and Anaconda, special efforts being made to get greater capacity within a given space by the use of new forms of jigs, such as the Hancock and Woodbury, and by other appliances.

The additions to the furnaces will include one new blast furnace 15 ft. by 56 in., and furnaces Nos. 4 and 5 will be connected in the same way as the Anaconda furnaces are connected, making one long furnace, and the blast-furnace capacity will be increased to the extent of something over 40 per cent.

In the roasting department 6 McDougall furnaces will be installed, making a total of 28 furnaces of this type.

The reverberatory equipment will be increased by the removal of an old furnace 42.5 ft. by 15 ft., and the construction of a new one 85 ft. by 17 ft., and this additional reverberatory capacity will require 8 more gas producers, reverberatory smelting at Great Falls being with gas fuel made from belt coal.

No additional converter stalls will be required, but larger converters, which have already been tried, will be increased in numbers.

Improvements at the Washoe Smelter, Anaconda, Mont.

At the Washoe Smelter, Mr. E. P. Mathewson, manager, the following improvements have been made since the last visit of the Montana Society of Engineers:

Concentrator. — It is the purpose to change the motive power of the concentrator from steam to electric, the steam units being held intact as a reserve. This electric power will be taken principally from the Missouri River Power Company's lines, it generating its current at its new dam and power plant near Helena. The motors to drive the mill are 1 200-h.p. capacity and so arranged on a quill shaft that the mill can be operated by steam or electricity with the least possible trouble. There are four of these motors built by the Bullock Manufacturing Company, and are of sufficient power that any one motor can drive three sections.

Calcine Building. — In this department there have been sixteen 6-hearth McDougall roasters of the Evans-Klepetko type added in the last three years, 8 of which are now under construction with the necessary additional flues and extensions to dust chamber and building. This makes 64 roasters in all, with a capacity of about 45 tons each, a total of 2 880 tons.

Reverberatory Building. — There has been considerable work done in these buildings in the last three years. Originally there were fourteen 19-ft. by 50-ft. reverberatory furnaces with forced draft, each having a capacity of about 100 tons per 24 hr. These furnaces have been dismantled one by one and replaced by furnaces of the following hearth dimensions:

One furnace	19 ft. by 116 ft.
One furnace	19 ft. by 102 ft. 6 in.
Five furnaces	19 ft. by 112 ft. 6 in.

With an additional furnace 19 ft. by 112 ft. 6 in. under construction.

The capacity of these furnaces is 300 tons of cupreous material in 24 hr. on natural draft.

Another decided improvement is the addition of two 375 h.p. Stirling boilers in tandem to each furnace, for the purpose of generating steam from the waste gases. These boilers develop 600 h.p. from the gases of each furnace, reducing the temperature of the gases from 2 800 degrees fahr. to 600 degrees fahr. Another improvement is the treatment of the ashes coming from the grates of each furnace by jigs, saving coke and unburned fuel to the extent of 10 per cent. of the fuel used.

Smelter Power House. — To meet the demands of increased

tonnage and production there have been added to the smelter power house 4 blast-furnace blowers and engines, 2 compressors for converter air, one 900-lb. air compressor for the local tramway, one 90-lb. air compressor and 1 hydraulic pressure pump. This brings the capacity of the blast-furnace blowers up to 360 000 000 cu. ft. of free air compressed to 40 oz. in 24 hr., and 60 000 000 cu. ft. of free air compressed to 16 lb. for converter use. The future construction in this building calls for two electrically-driven blast-furnace blowers and one electrically-driven 900-lb. air compressor.

Briquette Plant. — The rearrangement and improvements at this plant are unique. The original briquette machines have been discarded as inadequate. In their places 4 Chambers Brothers end-cut, auger-type brick machines are used, each having a capacity of 700 tons of material in 24 hr. The materials for the briquettes are conveyed from the storage bins by means of belt conveyors to the pug-mill mixers, the discharge of the mixer feeding to the briquette machine, which presses it through a die in a continuous bar, which is cut by a revolving cutter, peculiar to this type of machine, into briquettes weighing from 10 to 12 lb. The briquettes are conveyed by belt conveyors to small storage hoppers holding the amount needed for the charge. The mechanism of these hoppers is such that the entire blast-furnace charge train can be loaded in an incredibly short time by the single movement of two levers, which operate two shafts, having cams located opposite each hopper. The revolution of the shaft causes the cams to engage the latch holding the door shut, which door forms the bottom of the storage hopper and causes the latch to unlatch and drop the contents of the hopper into the car beneath. The doors are each counterbalanced by a heavy weight, so that when relieved of their load they are brought to their natural position ready for another charge.

Blast Furnaces. — Originally there were five 56-in. by 180-in. blast furnaces. In 1902 two additional furnaces of the same dimensions were added. These furnaces had a daily capacity of 450 tons of charge. In February, 1905, the first step towards making larger units was made by combining two of the 56-in. by 180-in. furnaces, — by removing the ends and filling in the space between, — making the entire furnace 56 in. by 51 ft. This furnace was so successful that two other furnaces were connected in like manner. This left three furnaces of the original size, and to further increase the capacity of the plant, the three were con-

nected as one furnace 87 ft. long. This makes the present equipment to be: Two 56-in. by 51-ft. and one 56-in. by 87-ft. furnaces from the center of tuyeres to the charging floor, with 14 ft. working column. The 51-ft. furnaces have 88 4-in. tuyeres and the 87-ft. furnace 150 4-in. tuyeres. The original capacity of the building with 7 furnaces was about 3 150 tons of charge; the present capacity being 1 600 tons of charge for the 51-ft. furnace and 3 000 tons for the 87-ft., or a total of 6 200 tons of charge. The larger furnace has decided advantages over the smaller; it has increased hearth area with but two ends to bind and hold the crusts, smaller radiating surface for the same hearth area, uses less coke and makes a very flexible unit, as any part of the furnace can be handled as the case demands; it is susceptible of repair without shutting down the entire furnace; in fact, the entire end of one furnace has been shut down, cleaned out, jackets changed, while the other half of the furnace was in operation.

Converter Building. — No extensive changes have been made in this building except the addition of two converter stands and a new slag conveyor in course of construction.

Electric Power. — The company has acquired the power plant of the Montana Power and Electric Company, at Flint Creek Falls, which has Georgetown Lake as a reservoir. The generators are being replaced with a type suitable for the demands of the new works and a pole line put in. It is expected that from 1 000 to 1 500 h.p. will be developed, part of which will be used at the Silver Lake pumping station, which supplies part of the water used by the plant in winter time. This pumping plant has been changed from steam to electrically driven pumps during the past summer; the remainder of the current will be used at the new works. A transformer house has been erected at the smelter,— one end being devoted to the Flint Creek power, with its necessary transformer, switch boards, etc.; also, three 3 h.p. motor generator sets for direct current; the other end for the use of the Missouri River Power Company as a transformer building, it transforming its current from 60 000 volts to 2 200 volts through four 1 675 h.p. Westinghouse transformers.

Flues and Stacks. — On the 13th of February, 1903, the construction of the new flues and stack was commenced and was completed September 11, 1903. The branch flues from the blast, roaster and reverberatory are 20 ft. wide and 15 ft. high, and of brick and steel construction.

The converter flue consists of two 7 ft. by 7 ft. flues; the flues are of the following lengths:

Blast	1 653 ft.
Roaster	488 ft.
Converter	703 ft.
Reverberatory	842 ft.

These flues merge into a "main flue" 60 ft. wide with side walls 20 in. high, and excavated so that the bottom slopes are at an angle of 30 degrees from the horizontal. At the bottom is a tunnel, having a brick arch roof, with hoppers every 10 ft.; from these hoppers the flue dust is drawn. The first part of this main flue is 60 ft. wide, with a brick and steel roof, and 1 200 ft. long. The remaining distance to the stack is 1 112 ft. of flue 120 ft. wide, with a steel roof having No. 9 steel as covering. The stack is of brick, 300 ft. high, 30 ft. inside diameter, with an inside core for a height of 145 ft., and a baffle wall 40 ft. high. The stack was completed in 67 working days. Total number of brick in the stack, 2 222 000; total number of brick mason days, 951; total number of brick per man days, 2 336. Some idea of the magnitude of the flue system may be obtained from the following figures:

Excavation	111 163 cu. yd.
Brick	14 188 000
Steel	1 896 tons.
Cement	9 122 bbls.
Powder	3 751 kegs black.
Powder	22 517 lb. giant.
Men days	114 410
Average number of men per day	440

General. — The record production of copper for this plant so far was made in March, 1906, and was 17 086 961 lb.

Some idea of the magnitude of the plant may be conveyed by the following figures:

Amount of ore that can be treated in 24 hr.	10 000 tons
Lime rock from adjacent quarries	2 300 tons
Coke used	650 tons
Coal for reverberatory use	500 tons
Coal for power use	500 tons
Water, gal. per min.	35 000
Men employed in and around Anaconda	3 000

Helena Power and Transmission Company.

One of the most important engineering works of the past year has been the construction of the dam and generating plant

on the Missouri River by the Helena Power and Transmission Company, of which Mr. M. H. Gerry, Jr., a member of this society, is manager and chief engineer.

The generating plant of the Helena Power and Transmission Company is located at Hauser Lake on the Missouri River, about 15 miles northeast from Helena, Hauser Lake being the name given to the post office and construction camp, in honor of ex-Gov. S. T. Hauser, president of the company. The plant, under a head of 70 ft., will, when completed, develop 20 000 h.p. The lake formed by the back waters of the dam will extend from the crest of the Hauser Lake dam to the tailrace of the Canyon Ferry dam and will cover an area of about 7 000 acres, inundating a considerable part of the Prickley Pear Valley.

The dam itself is a combined steel and reinforced concrete structure. Abutments and all foundations are of reinforced concrete, resting on bed rock everywhere except in the river bed. Where bed rock could not be found the foundations were made by carrying the excavation down well into hard pan gravel and driving timber piles closely together and placing concrete on top. The dam proper is a steel structure 620 ft. from abutment to abutment, having a slope on its up-stream face of 8.5 to 12. The lower, or up-stream line of plates, is flat and rests on a triangularly-shaped concrete rubble masonry fill, 50 ft. wide and 25 ft. high, extending entirely across the dam. The first series of plates is anchored to sheet steel piling, consisting of interlocking channel bars driven to bed rock and the whole covered with concrete. The next series of plates, extending from the flat plates to the crest, is curved and rests on steel bents 10 ft. apart. On top of the dam is a vertical steel construction, supporting 500 ft. of flashboards 14 ft. high, part of which consist of steel gates operated pneumatically. The upper part of the spillway, or apron, which is 500 ft. long, consists of flat steel plates resting on steel bents. The lower portion is a timber construction of rock-filled cribs, resting on bed rock or closely driven piles. On the toe line of the spillway is driven a line of interlocking channel bar piling to prevent an under-wash from the rear.

During construction of the dam the river was turned through six 8-ft. pipes laid side by side and anchored to bed rock and covered with concrete. These pipes were designed to take the entire flow of the Missouri River, except in spring high water, when the river spilled over the partly finished dam and over a temporary timber apron. The river is about to be shut off by means of six timber gates swung simultaneously into place from

above by hinges. In each large gate is a small gate to be closed after the water has reached the crest and is spilling.

The canal leading from the dam to the head-gates is perpendicular to the dam. It is 240 ft. long, 45 ft. wide at the entrance and 40 ft. deep. It was excavated out of solid rock and is lined throughout with concrete. The water from the canal is brought to the power house through five 12-ft. penstocks for power generators, and three 4-ft. penstocks for exciter generators. The head-gates are of curved steel plates with oak seals, the guides of same being embedded into concrete. These head-gates are operated from worm gears, operated by a motor.

The power house itself is a fireproof skeleton steel structure, filled with rubble masonry walls. It is 212 ft. long and 52 ft. wide, standing perpendicular to the dam. The tailrace and power house foundations were excavated from solid bed rock.

To each of the five penstocks an S. Morgan Smith water wheel unit, governed by Lombard governors, is connected, which in turn is directly connected to a 2 800-kw., 2 200-volt, 60 cycle, 3-phase, revolving field type Westinghouse generator, four of which are installed, and a place is left for the fifth.

The currents from these generators are led through duplicate distant control oil switches to nine 2 000-kw. step-up transformers. The transformers are of the Westinghouse oil-insulated, water-cooled type, and transform the current from 2 200 volts to 70 000, which is the line voltage.

The transmission lines are in duplicate from Hauser Lake to Butte and Anaconda, joining the Canyon Ferry transmission lines at a point near East Helena.

Work on the dam was started August, 1905, the Wisconsin Bridge Company having the contract for the steel dam; all other work being done by the Helena Power and Transmission Company. In the construction from three to five hundred men were continually employed up to the present time. In the neighborhood of 2 500 tons of structural steel and 32 000 bbl. of cement were used. All material was transported by means of horses and wagons over a difficult road, a distance of 12 miles from Iron Siding, a point on the Great Northern Railway.

Hauser Lake, for the past sixteen months, has been the busiest little city in Montana.

From the generating plant a large part of the electrical energy is transmitted to the substation at Butte, Mr. W. L. Miller engineer in charge.

The transformer substation will transform electrical energy

transmitted from the Missouri River, the ratio of transformation being 60 000 to 2 200 volts.

The transformers will be arranged in two banks of three each, the capacity of each of the said transformers being 1 675 kw.; in addition to these six transformers there will be one spare transformer of the same capacity as any one of the six which may be connected to take the place of any transformer if the same becomes disabled. The normal capacity of this substation is about 15 000 h.p.

This substation has a floor area of 450 sq. ft.

The steam auxiliary plant consists of six 500 h.p. Babcock & Wilcox water tube boilers and two 2 000 kw. Westinghouse-Parsons steam turbines. The steam is generated at 200-lb. pressure and 125 degrees superheat. The steam turbines are run condensing, and the circulating water is cooled by means of a cooling tower 23 ft. wide, 81 ft. long and 65 ft. high.

The boilers are equipped with Roney stokers, and are laid out on the unit system, there being three boilers to a battery, and one battery to a steam turbine. Each battery is connected to its own self-supporting steel stack 9 ft. in diameter and 200 ft. high.

The auxiliary steam plant covers an area of 17 200 sq. ft.

Another substation is located at Anaconda, at the Washoe plant, quite similar to the one at Butte, but it has only four transformers and no steam turbines.

General Outlook.

Every citizen of Montana should congratulate himself that he lives in the treasure state. Notwithstanding the advance made in every industry in the state during the last year, the new year starts out with the promise of greater achievements, which will bring greater wealth and power to our beloved Montana.

My address would not be complete if I did not make mention of another industry in which we all take pride, and that is the Montana State School af Mines.

Located as it is on the foot hills west of the city, in the shadow of the Big Butte, overlooking the great mining camp, it is a typical location for a great mining school. The young men have every opportunity to keep in touch with the latest methods of mining and metallurgy. They can see the practical application in the mines and smelters of the lectures to which they listen in the classrooms.

The school is well equipped, and is fortunate in having an able corps of professors, whose success is shown by the class of young engineers that is turned out each year. I have tried many of them, both in the practical hard work of mining and in the engineering offices, and in every case the report of the superintendent or chief engineer has been " he is a good man."

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1907, for publication in a subsequent number of the JOURNAL.]

REINFORCED CONCRETE: ITS LIMITATIONS.

By Carl Gayler.

[Read before the Engineers' Club of St. Louis, January 2, 1907.]

Ever since I have had the honor of being a member of this club, I have made it a rule, whenever I had learned something new or acquired some new experience, to bring it before the club in the shape of a paper, and so now, feeling that I have again "something to say," I enlist your patience for a short hour. Of course the subject is on reinforced concrete; what else could a structural engineer speak about nowadays, when we are in the very high tide of this wonderful material, when wood and steel and cut stone are going out of fashion, when the engineer who is not ready and able to use, intelligently, reinforced concrete for anything in the building line, from a fence to an office building, from a sewer to a railroad bridge, might as well take down his shingle and retire?

The subject before us being "Limitations of Reinforced Concrete," it seems appropriate to begin with "Limitations of this Paper." It will not deal with the whole range of the subject, for then I should in a few hours be speaking to empty benches; no new formulas or scientific investigations will be brought forward, for under the wise laws of division of labor, we designing engineers can leave these safely in the hands of the professors and specialists; you may, or, rather you will, discover other "limitations" of this paper; but then, such as it is, offering some homely truths found in actual experience, some considerations worthy at least to be discussed by you, and also deduced from actual experience, you are asked to listen to the same.

Why is concrete reinforced? Because, the ready answer is, the reinforcement imparts to concrete the inestimable quality of resisting shear and tension, as well as compression. But there is another reason of hardly less importance: reinforcing rods, judiciously placed in the body of concrete, transform it into a monolith. Now the generally prevailing opinion is that concrete itself without reinforcement, in drying, contracts into a monolith, but this is in most cases, at least in the shape in which we generally use the material, not the case. Unless we have to deal with concrete in the shape of a cube, or a globe or a prism of

simple shape, no concrete forms into a monolith, *but into a number of monoliths.* It contracts in drying on what may be called lines of least resistance into several pieces of concrete, separated by more or less open cracks, and it is the fact that this can be prevented by embedded steel rods, properly called "shrinkage rods," in combination with the effect of the reinforcing rods used to resist tensions, that has given reinforced concrete its high place among building materials.

Some years ago we listened in this club to an interesting paper on continuous street-car rails in which the remarkable fact was explained that street-car rails can be made continuous without being damaged or torn apart by changes in temperature, as the friction between the surface of the sides of the rails and the pavement is sufficient to hold the rail in place. Substitute in this last sentence the embedded steel rods for the pavement and the mass of concrete for the car rail, and we have stated the principle of the shrinkage rod. It is the internal stress caused by shrinkage of so many square inches of concrete against frictional resistance of so many square inches of embedded surface of steel.

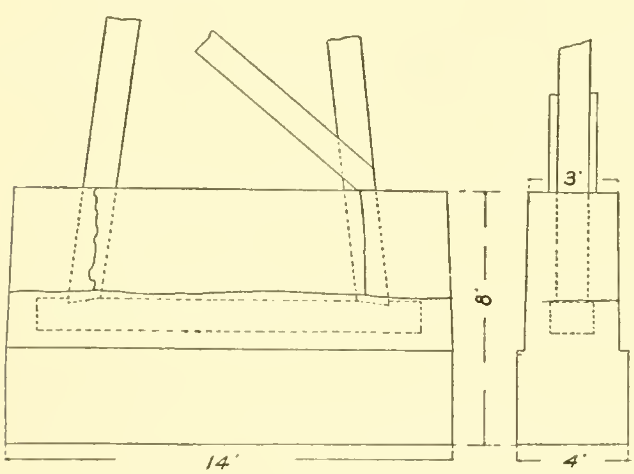


Fig. 1.

Let me give you a few illustrations of the way in which plain concrete in drying separates. The figure before you shows a small concrete pier put up around the base of a wooden trestle bent. The pier being of rectangular shape, about 20 ft. long, 4 ft. thick and 6 or 8 ft. high, might have been expected to form a monolith and would probably have done so if the inclosed timber had not prevented it. You notice the wide crack along the sill and the two vertical cracks along the posts. Two sets of shrinkage rods, one set horizontal to prevent the vertical cracks and another vertical set would have prevented the mischief.

Some years ago, at a time when Portland cement concrete, without reinforcement even, was a new thing, I had occasion to extend the wings of a small highway bridge, using concrete for the extension and stepping it off, as you see in Fig. 2. The

result was a pretty illustration of how such concrete, regardless of the good intentions of the engineer to form a monolith, separates into a number of them. It is hardly necessary to add that the same engineer, to-day, would not design any such graceful stepping-offs, and would probably insert some shrinkage rods.

Some of you may have had occasion to build a concrete coping with an iron railing on top of it. Now nothing is more natural, or better, than to embed the ends of the railing posts in said coping. But I can state as an absolute fact, observed not only in St. Louis but also in other cities, that of twenty such railing posts, whether they are of cast iron or steel angles, not less than ten will crack a 12-in. or 14-in. coping, 3 ft. to 4 ft. wide at right angles to the line of the coping. The explanation is simple enough; being hindered by the railing posts from contracting into one continuous monolith, the coping contracts into a number of monoliths, each as long as the distance between the railing posts. The remedy suggests itself also. But in this example, insignificant as it may seem to you, we are confronted with another very important problem. If, as we have seen, 10 or 12 in. of 4-in. by 4-in. steel angle, inserted into a body of concrete of 3 to 5 sq. ft. area, are liable to crack the concrete clear across, isn't it apparent that we should look on all embedded reinforcement as, under certain conditions and proportions, an element of weakness instead of additional strength?

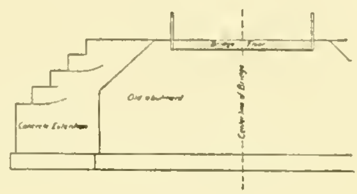


FIG. 2.

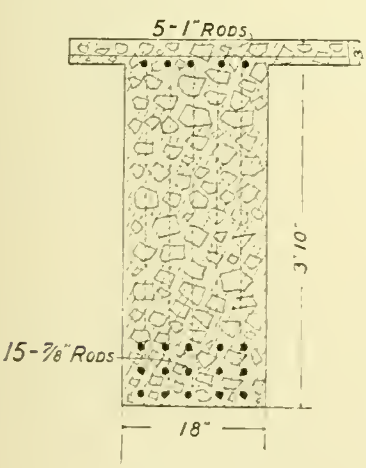


FIG. 3.

We reinforce concrete by steel rods, and we do so successfully with 0.75-in., 1-in., or even 2-in. rods, but what, in view of the above, is the result if we employ still larger rods, or I beams, or steel rails, or, as is daily done in architectural work, if we use a number of small rods, close together, forming a very cluster in a narrow beam?

To illustrate this latter point I have taken at random a section of a reinforced concrete girder from one of the technical journals and shown it in Fig. 3.

I may here remark incidentally, which will also apply to one or two other points brought out later on in this paper, that the architects are in a far more favorable position than we

engineers, since they have a way of plastering, casing in, covering up, in a word, of hiding their work, which we have not. Longitudinal cracks along the reinforcing rods of their girders and beams, and we find here and there mention of such cracks in the publications, do not show in their work.

Now the question is: When have we reached the point where the inclosed metal separates and cracks the concrete instead of being firmly gripped by the same? It is not at all the mere surface contact between the two materials which constitutes the efficiency of the reinforcement, but the fact that concrete in drying shrinks, which shrinking produces its gripping effect on the reinforcement, and it is therefore all important that this shrinking should take place towards the metal, not from it.

It is still customary, although not to the same extent as in former years, to build floors of buildings and viaducts by means of concrete arches between I beams. The centers of these small arches are generally left in position till the concrete is tolerably hard. But the mass of concrete keeps on drying and consequently shrinking, for a long time after; the concrete is generally of too great a thickness to allow of sufficient elasticity to conform to the new span, and the consequence is that a crack forms, either on one side or on both sides of the I beams, *i.e.*, we have not an arch at all but a solid stone, concave below and resting principally on the bottom flanges of the beams. This is no mere theory. I have built hundreds of such arches in former years and hardly ever without meeting with these annoying cracks along the beams. There is a viaduct over the railroad tracks in this city whose floor consists of such concrete arches between 24-in. I beams which carry the street-car rails. Now if during a heavy shower you should be seeking shelter under said viaduct, as has happened to the speaker, you would be glad to have an umbrella over your head. Still, although not perfect, such arches are useful structures and generally answer the purpose very well.

This subject of the shrinking away of concrete from the steel work, instead of clinging to it, is very fascinating and worthy of the closest observation. We have been so educated into the belief that concrete and steel have, so to say, an affinity for each other, that it is not easy to get rid of that impression. Concrete in fact has no affinity whatever for any other material. We all know that it is next to impossible to make concrete join completely a hardened surface of concrete, or masonry or cut stone or any other material, *not excluding steel*. There are a

number of steel plate girder bridges in this city with concrete floors, on which a concrete wheel guard is built up against the web of the plate girders. Surely this is a case where the embedded steel surface should appear to the naked eye as a unit with the concrete, but on a hot sunshiny day you may notice here and there a very fine crack separating the two materials for considerable length.

To sum up:

(1) Concrete in hardening grips embedded steel under conditions which depend on the relative size and shape of the metal.

(2) Concrete in hardening has a tendency to separate from any adjoining surface, due to its own shrinkage. Which rules can be well illustrated, as in Fig. 4.

The above considerations apply to the whole field of reinforced concrete work and furnish, for instance, a strong argument against the Melan reinforced concrete arch and in favor of the reinforced concrete arch where steel rods or bars are so dis-

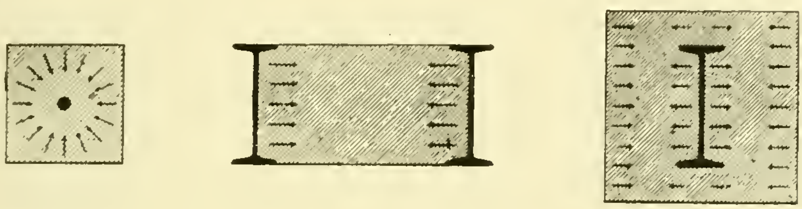


Fig. 4.

tributed over the intrados and extrados that the stresses are readily imparted to the surrounding body of concrete. This is confirmed by the experience of the Passaic River bridge in Paterson, N. J., where the arches in their downfall separated into longitudinal sections along the lines of the I beams. The downfall, however, as you know, was caused by undermining of the foundations during an unusual high water, not through any fault of the system of the reinforced concrete.

But there is another serious limitation to the successful use of reinforced concrete, and this paper has been brought before you in vain if it fails to impress you with its great importance. I refer to the question of proper inspection.

We have, all of us, inspected material, wood, iron, steel, stone, almost any building material used by mankind, but now a problem in inspection has come up such as we never before had to deal with. Assume, to make my argument clear, the case of a steel structure, either the skeleton of a building or a viaduct, and assume further that said steel structure is built without any

inspection, either at the mills, or at the shop, or during erection. Now I will not go so far as to say that the structure will be as good as if built under inspection but it will be *nearly so*. There may be flaws in some of the plates, ragged edges to some of the shapes; there may be here and there a loose rivet; in putting the work together there may be some maltreatment of the metal; some member may after erection be slightly out of line; but after all we shall have a safe, serviceable structure, provided that the plan is correct. Let us now consider the same structure built in reinforced concrete, on a plan equally correct with the plan for the steel work, under the same conditions, no inspection or tests of material, no supervision of the manner in which the rods are placed, more than that whether they are placed at all,— and this is no supposititious case but has to my knowledge been experienced again and again, — no control over the all-important question of continuity of operation, and the plain fact is that we shall not know what we have got at all; we have relied entirely on the honesty and efficiency of the contractor, *i.e.*, we have shirked our duty as engineers under circumstances such as we were never before confronted with. While in the case of the steel structure the possible range between a structure built under thorough inspection and under no inspection is from an excellent structure to a fairly good but at any rate safe structure, the range of the reinforced concrete work under the same conditions is all the way from an excellent structure to absolute destruction.

In confirmation of the first statement I can, from memory, quote Theodore Cooper, who some years ago expressed himself somewhat to this effect: " Every recorded case of failure of an iron bridge (leaving out of consideration accidents through derailments, washouts, etc.) can be explained through faulty designs, never be attributed to poor material or workmanship." If I recollect rightly this was brought out in the discussions arising from the failure of the Tay bridge in Scotland. In confirmation of the second statement we can point to the numerous recent failures in reinforced concrete work.

To illustrate the above-mentioned question of continuity of operation (I like illustrations, they save words and they impress):

Let G, Fig. 5, represent a heavy reinforced concrete girder, B, the beams supported by the same. Now the best method of carrying on such work is to do it uninterruptedly, as far as possible, or, at least, to complete girder G at one time with proper recesses for the beams, and then to finish each beam B at one time.

But take the case that the work is not done on such lines, that the foreman is incompetent or careless, the contractor, as is often unavoidable, absent from the work, — what is to prevent said careless foreman from finishing girder G by itself, without recesses for the beams and to build in afterwards, perhaps after an intervening Sunday, the beams B; or supposing the work done under a glaring sunshine — and I have had cases where I felt like praying for clouds and rain — and the heavy girder G finished to half its height and then let go for a time without troubling about sprinkling,— imagine such and similar conditions, which to a greater or less extent are bound to happen, unless you are lucky enough to have an excellent foreman who relieves you of your responsiblilty, or unless you have the most rigid and intelligent inspection, where is the very safety, not to say excellence, of the work? The success of reinforced concrete work lies in the inspection to a far greater degree than with any other class of building material. And the difficulty and expense of obtaining such inspection, which is generally only to be obtained in government work, municipal work not blighted by politics, or in the thorough organization of railroad work, but seldom in private undertakings or in works built in out-of-the way localities, are in my opinion to be classed among the limitations of reinforced concrete work.

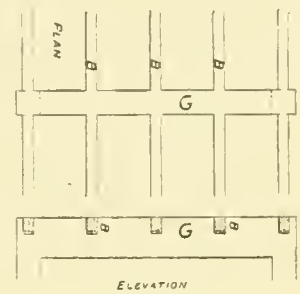


FIG. 5.

Of course, this applies with much less force to foundation work, heavy piers or abutments, etc.

Like the preacher, I might have subdivided this paper into "firstly," "secondly," and so on and the headings would then have been somewhat as follows:

(1) Generally.
(2) Inspection.
(3) Science of reinforced concrete.
(4) Details of construction.

So that we have now reached the problem of the so-called science of reinforced concrete and a very troublesome problem we shall find it, for we are dealing with a material whose physical qualities and even shape undergo great changes for some time after it has assumed its duties, a material the computations of which, more than that, the very definitions of whose properties, are as changing as the winds that blow.

This is a strong statement and needs explaining. I promise

to be as short as possible; the question of shear and the theories of stresses in more complicated structures, as arches, retaining walls, etc., fascinating as they are, will be hardly touched on; instead let us assume the simplest possible case and take up the computation of a reinforced concrete girder, beam or slab composed of ingredients according to ordinary practice, at one particular time, say a few months after the concrete is laid. We have thus discarded the above-mentioned differences in the strength of the concrete at the different periods of hardening, also the question of different qualities of concrete composed of ingredients mixed in different proportions, laid with different amount of wetness, etc.

Now we are all familiar with such definitions as neutral axis, modulus of elasticity, factor of safety, ultimate strength, etc., and we meet them again in the calculations of the reinforced concrete girder, beam or slab, but their character and meaning have changed.

While with steel beams these definitions are definite and constant, with the reinforced concrete beams they are more or less indefinite and variable.

The modulus of elasticity of structural steel is constant within the elastic limit and for the different kinds varies hardly more than 5 per cent. from the generally assumed 30 000 000 lb. per sq. in., but the modulus of elasticity of reinforced concrete is variable, decreasing under increasing pressure, and its variations in strength have been stated at ranges varying all the way from 750 000 lb. to 4 000 000 lb. per sq. in. The generally assumed value of 3 000 000 lb. per sq. in. for the modulus looks like a rather bold compromise. Mr. Christophe, a French authority on reinforced concrete — and it is to the French that we owe our theories on reinforced concrete — suggests the abolishing of the very name of modulus of elasticity of reinforced concrete.

From the fact that the modulus of elasticity of steel is constant while that of reinforced concrete varies, it follows that the neutral axis is variable, rising above the middle of the beam with the increase of the stresses in the beam; and it follows furthermore from the variability of the modulus of elasticity of reinforced concrete, *i.e.*, the variation in the compressibility of concrete, under varying pressures, that the center of gravity of the compression stresses in the concrete varies and also that we have quite a variegated collection of stress-strain diagrams, with which, however, I will not trouble you.

All authorities agree, furthermore, that the term " factor of

safety " is not, strictly speaking, applicable to reinforced concrete work, because cracks open in the lower surface of the concrete before the steel is stretched beyond a safe strain and before the upper part of the concrete is compressed to its safe limit.

Yet, in spite of these uncertainties, variable factors and characteristics, the fact, absolutely proved by daily experience all over the civilized world, remains that reinforced concrete in the shape of beams and slabs, if properly proportioned and handled, is a material of inestimable value, safe, fireproof as no other material, everlasting and relatively cheap; so theories and formulas which covered the case had to be evolved and with an astonishing amount of ingenuity and learning they have been evolved. All honor to the men who gave us these theories. It is true the first formulas looked rather formidable and it was expecting a good deal from the busy engineer that he should familiarize himself with their intricacies. But the long perplexing formulas have had their day and simple rules which appeal directly to the understanding have taken their place.

As you all know, the moment of resistance of a beam, girder or slab is to-day expressed as the product of the stress in the steel reinforcement into the effective height, *i.e.*, into the height from the center of gravity of the steel rods to the center of gravity of the compressive stresses of the concrete, with the condition that the proportion of square inches of steel to the number of square inches of the concrete shall be at a certain ratio. In other words, the moment of resistance of any reinforced concrete girder, beam or slab is strikingly similar to that of any steel girder or beam. Considering the amount of knowledge and ingenuity displayed in the theoretical researches it seems like an unkind saying, but it is true nevertheless, that we are hardly justified in speaking of a " science of reinforced concrete " at all.

It might interest you to see just what cross sections we obtain for a reinforced concrete girder if we apply such formulas and proportions as are the daily practice, and to compare the same with the cross sections of a steel beam and of a wooden joist of the same strength. In Fig. 6 a few such sections are shown, drawn to the same scale.

Assumed units: extreme fiber stress in I beams	16 000 lb. per sq. in.
Extreme fiber stress in reinforcement	,, ,, ,, ,, ,,
Ratio of areas of steel to area of concrete	1.25 per cent.
Extreme fiber stress in wood	1 200 lb. per sq. in.

The results are rather startling and it must be confessed

that for clumsiness, unsightliness and apparent wastefulness the reinforced concrete girder, at least in its simplest shape, is without a peer in the realm of building materials.

In using the word " wastefulness," that part of the concrete which lies below the neutral axis is referred to. It really does seem as if very little use were made of the strength of this portion

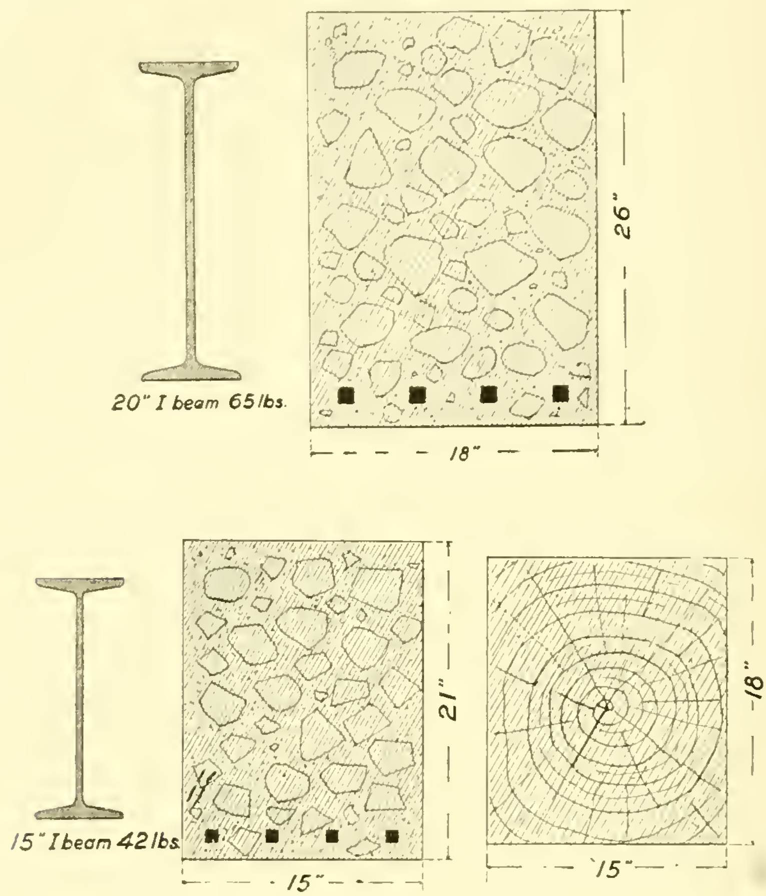


Fig. 6.

of the concrete, at least in girders where the shear is taken up by steel.

In mere fairness it ought to be said right here that the reinforced concrete slab, used as floor for buildings and viaducts, is, in every respect, economy, fireproofness and strength, unequaled by any other building material; but as our subject is the " limitations of reinforced concrete," such a eulogy does not come within its scope.

Let us take another illustration, the comparative cross sections of a column for a building in cast iron, steel and reinforced concrete, all of equal strength. These cross sections are particularly interesting because they are taken from actual experience.

Plans had been prepared for a 5-story warehouse, using cast-iron columns, steel beams and concrete floors. For weighty, financial reasons, reinforced concrete was substituted for all the metal work and the relative cross sections of the cast-iron columns and of the substituted reinforced concrete columns, the latter, as planned by the contractors themselves, drawn to the same scale, from the first story of said building, are shown in Fig. 7. A section of the Z bar column of the same strength is added.

The unit compression of the concrete was assumed at 500 lb. per sq. in., of the reinforcing rods at 7 500 lb. per sq. in. The

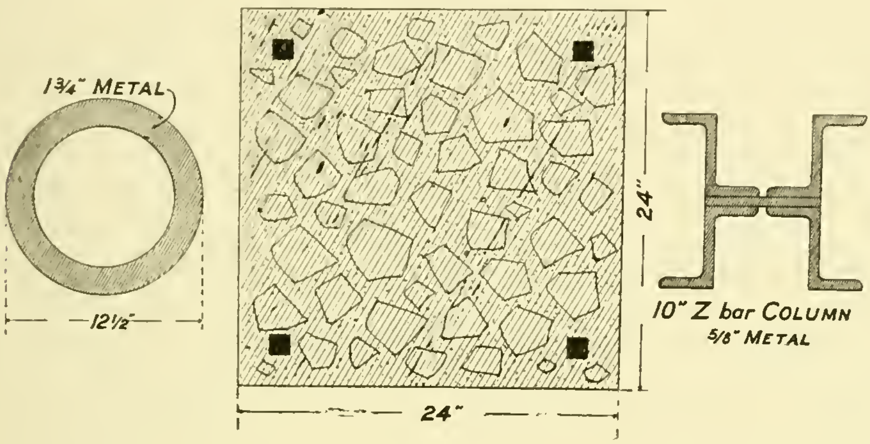


FIG. 7.

sections of the cast iron and of the Z bar columns were taken from Carnegie's handbook.

Allowing 400 lb. per sq. in. on the concrete, instead of 500, would require a column 27 or 28 in. square.

From this and similar examples, taken from ordinary daily practice, I am absolutely convinced that the reinforced concrete column will never be a serious competitor of the steel columns for high buildings, unless we can produce a concrete far superior to the concrete we are using to-day. The steel column, protected by concrete against fire, will remain the best and safest column for high buildings, not only because it is safer and takes up less room but also on account of its elasticity, which enables it to resist tornadoes and earthquakes better than any other known material.

If the use of reinforced concrete for certain parts of structures, as we have seen in the example of columns of high buildings, or of girders where the architectural appearance is of importance, is limited through the competition of steel, so on

the other hand some points can be mentioned in which reinforced concrete is at a disadvantage compared with mason work or cut stone work.

We will not again refer to possible cracks which may occur in spite of all precautions, expansion joints and shrinkage rods, but it is certain that the surface of concrete becomes unsightly through efflorescence, discolored and liable to show a number of fine, so-called hair, cracks. As this fact, however, has been ably discussed by other engineers and as it is very likely that this annoying quality will be successfully eliminated through special treatments of the surface, we will not lay too much stress on it.

But there is another limitation to the use of reinforced concrete which to my knowledge has hardly ever before been brought out, — the low ultimate compressive strength of concrete.

Text-books give the ultimate compressive strength of granite as from 5 000 to 18 000 lb. per sq. in., of limestone from 4 000 to 16 000 lb. per sq. in., of sandstone from 2 500 to 10 000 lb. per sq. in. Prof. Ira D. Baker gives the following list:

Trap rock of N. J.,	ultimate	crushing	strength,	20 000–24 000	lb. per sq. in.
Granite,	,,	,,	,,	12 000–21 000	,, ,, ,, ,,
Marble,	,,	,,	,,	8 000–20 000	,, ,, ,, ,,
Limestone,	,,	,,	,,	7 000–20 000	,, ,, ,, ,,
Sand stone,	,,	,,	,,	5 000–15 000	,, ,, ,, ,,

As the ultimate compressive strength of the different kinds of concrete is from 2 000 to 3 500 lb. per sq. in., this material has to be classed among the soft sandstones. This point is of the utmost importance; it explains the unwieldy size of reinforced concrete columns, also the fact that the surface of concrete has to be protected, particularly at corners, against abrasion, as, for instance, from passing vehicles, heavy floes of ice, etc., and the failure of concrete as a material for street or alley pavements without an extra wearing surface which can from time to time be renewed. There is no doubt that the low ultimate strength of concrete in compression will limit the practicable length of span of concrete arches, whether reinforced or not, and it will also be an important factor in the design of high retaining walls, chimneys, etc.

The time is too short to enter into the question of use of reinforced concrete for retaining walls, but the following statement, based on the experience of many years, may be permitted:

In view of the great uncertainty as to the amount and

direction of earth pressure on a retaining wall, we should always keep in mind that, after all, a retaining wall resists through its bulk, its mass, whether it is built of masonry or of plain concrete or of reinforced concrete. A reinforced concrete wall carefully designed in all its component parts, face work, buttresses, projecting sole and so on, without being ponderous enough to resist the horizontal component of the earth pressure, is like a carefully designed reinforced concrete arch with insufficient foundations.

Taking up the question of details of construction:

Stress has been laid above on the gripping quality of the concrete on the reinforcement, which is indeed the very basis of the success of reinforced concrete construction. Now we find it to be general practice to cover the steel rods in the bottom of a reinforced concrete girder by concrete of a thickness of 1 in. or 1.5 in., and it is customary to consider this as sufficient covering because it is a sufficient protection for the steel in case of fire. This seems to be true; but how can we expect this thin coating to grip the steel rods up to their elastic limit, especially steel rods of an inch and more section? I am aware that this is a matter of judgment and is not covered, to my knowledge, by any theory; but from intimacy with the material it seems to me that a thickness of 3 or even 4 in. for heavy rods would be more appropriate, more particularly so in girders which are exposed to shocks. This applies not only to the beam or girder but to the reinforced concrete arch, the reinforced concrete retaining wall, in fact to any structure where the concrete has to take up the stress or increments of stresses in the imbedded steel work. Let us take, as an illustration, two cases which, though not strictly parallel, are analogous enough to be compared, — the anchor bolts in a pier and the steel reinforcement in the intrados of an arch. We will have the anchor bolts without a washer, because these washers have a tendency to crack the concrete, but held by the gripping effect of the concrete on its surface. Would such anchor bolts be considered effective by any engineer if placed within an inch or two of the edge of the pier, and under what argument or theory are we justified in taking a different rule for the steel rods in the intrados of an arch?

And this brings up another point in the use of such rods: the transmittance longitudinally of their stresses.

In proportioning reinforced concrete columns for a building it is customary to include the sectional area of the steel rods placed near the corners of the column as effective against com-

pression, and it is also customary to make such rods of the length of one story without any connection with or any bearing on the rods in the columns of the next story, *i.e.*, the tiers of columns are so built that the ends of the reinforcing rods press on concrete.

We find this point, however, fully covered in the new San Francisco building laws, as follows:

" When vertical reinforcement is used in columns, such as rods, they shall have full, perfect bearings at each joint, and such joints shall occur only at floors or other points of lateral support, and a tight fitting sleeve shall be provided at all joints of vertical reinforcing rods."

More than this, there is an excellent provision in these same laws, for the transfer of wind stress in such columns:

" In case of buildings in which allowance must be made for wind pressure, the reinforcing rods of concrete shall be connected by threading the rods and by threaded sleeve nuts, or threaded turnbuckles or methods equally effective and satisfactory to the Board of Public Works."

It is not easy to see why these or similar rules should not be applied to other reinforced concrete structures as, for instance, high chimneys or reinforced concrete arch bridges. Any engineer who has had to do with the placing of reinforcing rods in a concrete arch where the present practice is to transfer the tensile stresses in each line of rods by the simple process of extending the ends of the rods a few feet beyond the joints, sometimes bringing thus the projecting ends in close contact with the adjoining rods, will agree that this primitive method should be replaced by efficient, direct joints.

The reason why these last named points were included in this paper is not that they are limitations of reinforced concrete work in themselves, for they are easily altered, but because any improvement in the same implies, necessarily, increased cost. Now in the fierce competitive struggle going on between steel work and wood work on one side and reinforced concrete work, the tendency has been altogether too much in the direction of introducing reinforced concrete on the claim of reduced first cost and at the expense of first-class work.

One of the most striking instances of the tendency to cheapen reinforced concrete work is the fact that reinforced concrete arch bridges in our country are built either with utter disregard of the laws of expansion and contraction under changing temperatures, or by assuming variations of temperature to

suit the requirements of a cheap arch. It has, for instance, been proposed, in all seriousness, to limit in designing reinforced concrete arches, the extremes of temperature to 26 degrees above and below the temperature at which the arch is supposed to be built! To my knowledge, this is the only recorded instance in the history of civil engineering in which, instead of building the works according to the laws of nature, an attempt is made to adjust the laws of nature to the work of man.

Let reinforced concrete work stand on its merits, not on the claim of greater cheapness alone; it can well afford it.

Darwin, somewhere, lays down the law that erroneous opinions are comparatively harmless, because they produce at once in the minds of the listeners a healthy spirit of opposition and criticism, but that it is of the utmost importance that facts are recorded correctly. Well, the facts I have stated are correct; if you think some of the deductions drawn from them are erroneous, the harm, on the quoted high authority, is not very great.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by June 1, 1907, for publication in a subsequent number of the JOURNAL.]

FIRE PREVENTION APPARATUS.

By John Richards, Member of the Technical Society of the Pacific Coast.

[Presented to be read before the Society, March 1, 1907.]

The writer of this monograph has for twenty years paid for space in a San Francisco building accredited as fire and earthquake proof, in which he kept his stock in trade: references and data relating to engineering and the industrial arts, collected during forty years past in this and other countries. To have this property swept away without a scrap remaining, at an age when memory is too weak to reproduce anything of value, leads one to think of the causes or circumstances that permit such a loss, and a few such thoughts form the subject of this short communication to the Technical Society of the Pacific Coast.

Nature has furnished us with a copious and effectual means of quenching fire, that is, water, and has provided this means in abundance. If, in San Francisco and other cities situated on the shore of the sea, means are not adequate to convey and apply this water, it becomes a reflection on our engineering skill, chargeable, as one must think, to the reasons that prevented the Arkansas pioneer from repairing his roof, — " when it did not rain his house was as dry as any other house."

Here along our water front is lying ready to hand water without end, situated only a few feet below the plane of the most dense and valuable part of the city. The arts have provided us with simple and effectual means of applying this water and impelling it under any pressure and to any distance required, so that the problem of fire prevention becomes narrowed down to the single feature of " conveyance."

To this point of conveyance then is confined the problem of fire extinguishing. It is not a very easy problem, of course; that is, the many methods that may be made use of produce an intricacy of the problem and lead to a wide range of opinions, and this is often the basis of inaction; in fact, is a direct cause of inaction.

This and all similar problems should be approached by generalization, that is, by considering generally the principles that apply, and when these are ascertained, concrete plans of a

logical and conservative nature will appear and will follow to successful consummation.

The conditions are not at all intricate, and resolve themselves into cost or investment, maintenance, flexibility of distribution, celerity, disturbance by earthquakes, area of supply and such constructive precedents as there are to observe.

I will remark briefly upon some of the conditions, first pointing out that this city, or, as I should say, California, pays less attention to precedents than any other part of the world and on the whole has gained by originality and boldness in her engineering; hence is prepared to grapple with the fire problem where departure from custom seems desirable.

Passing over the first two elements of fire extinguishment, original supply and means of impelling water, and speaking of the subject of conveyance, first is the matter of investment. In respect to conduits of any kind it must be stated that the cost of these is governed almost directly by the velocity at which the water is conveyed. It will cost approximately four times as much to convey water in conduits, at the rate of 5 ft. per sec., as it will to convey the same water at 20 ft. per sec.

This, for economy, points to initial propulsion and pressure. Any other system would involve cisterns for storage, a subdivided and fixed means of impulsion and distribution, and, lacking power of concentration, would amount to ten times the cost of attendance and maintenance and in a certain sense would be inflexible after all, that is, it could not be concentrated on a particular area; moreover is liable to derangement if not extinction by earthquakes.

To these impediments of slow conveyance and sub-divided impulsion may be added the cost of land area in the most expensive parts of the city. Initial impulsion may be performed on the water, saving thereby not only the expense and use of the land, but at the same time the plant, if we may term it so, would become portable, furnishing a ready means of rapid concentration in case of a conflagration.

This, you will say, points to a fire boat or barge. So it does, but with a difference. Such a boat should be a stable barge provided with units of rotative pumping apparatus capable of working up to the required volume and pressure, operating through pipe lines of one to two thousand feet. The engine shaft should extend through the pumps to a simple steam engine and be clutched to a propeller shaft, also to the pumps.

On the main deck of this barge, and level with the pier

floors, there should be carried, in suitable racks, one to two thousand feet of sheet metal or other pipes of 5 to 8 in. bore, made in sections about 50 ft. long, having at the ends plain flanges to be connected with "U" clips driven with hammers; not screw threads or other ingenious connections, but something any one can apply or remove instantly.

Hose I do not consider suitable because of its perishability, uncertain strength and heavy unwieldy nature. Of course initial sections of the conducting pipes could be of flexible nature to accommodate angles and movements of the barge, but even these could be of metallic structure.

Pipes of this kind may be laid in the gutters of the streets by wholly unskilled people at the rate of half a mile in half an hour, and for different distances in proportion. Shields for crossings when streets cannot be barred, and other details of use, would offer no impediments of a serious nature.

A tolerably long and extensive experience in the impulsion and conveyance of water has suggested to me the means here briefly described of dealing with fires within a mile or so of the water front and for shipping. For districts farther from the water, stationary plants of a like nature would be required to attain celerity of action, especially in residential districts, but to save the mass of a city lying on a shore, plain simple fire barges constructed with the features such as named seem most efficient and can be provided at a very moderate expense.

At this point of writing the paper of Mr. Steeb on "Fire Protection Engineering," recently read at Cleveland, Ohio, came to hand, and while the diversified topics can hardly be called "engineering," the paper is one of much value, especially in pointing out the vast economic importance of protection from fire.

The reference to fixed high-pressure main pipes now covers an extensive field now existing, if there is included the dual service of fire and service pressure in the same pipes. This latter scheme is old and has been common for sixty years past without, however, attaining the confidence that its nature suggests.

Many of the larger towns in California have provisions for high pressure in the distribution pipes attained at small expense and expedient in nearly all cases over centralized areas; but there are limitations of various kinds, especially in San Francisco, and other means will have to be provided where fresh water supply is limited and is in the hands of a private company.

Mr. Steeb's idea of special fixed mains is open to the objections already pointed out, and others. It calls for a prohibitive investment and conflicts in the streets with the numerous and increasing structures that must be contended with there. It is too vast a thing for emergency use and its maintenance for salt water would prove a burden calling for serious consideration.

One thing in the paper referred to is worthy of note. Mr. Steeb mentions that in Cleveland the impulsion for the fire service is from boats, or, as stated, "fire tugs," which, as understood, means a hybrid kind of craft adapted for the two functions of towing vessels and pumping water. This is not unusual, is common, indeed, and is a mistake. A boat or barge fitted for impelling water for fire purposes should be constructed for this special function, in which form the cost or investment would be inconsiderable in comparison, and the adaptation complete, and the same structure could carry its own conduits.

In this latter feature lies the main point which I am attempting to present, and of its practicability I have not the least doubt. It is merely an extension of the present fire system existing all over the world, namely, a portable impelling engine and movable hose or water conduits thereupon, but augmented to a volume sufficient to quench any fire that can occur in this or any other city situated on the seashore.

In the adoption of such a system there is not called into use any feature that is not well understood by all competent engineers and mechanics, except the rapid junction of pipes. There is not a detail but can be contracted for under guarantee with firms here in the city and at a tithe of the expense involved in such other schemes as have come under notice.

DISCUSSION.

Mr. Thos. Morrin. — Mr. Richards rightly says that "it is not an easy problem"; but all will not agree with him, as I surely do not, that the manner of securing the water only when it is needed is the best protection.

First, I am convinced that while the salt water may be the best element for extinguishing fires, it is also the most destructive agent possible in its effect on some classes of goods, which would not be totally ruined were they saturated with fresh water. Especially is this true when we consider the filthy condition of the water along the wharves and front of the city, carrying, as it does, not only the sewage and seepage of the most densely populated portion of the city, but also much of the wash and by-

product of the chemical and other manufacturing works that empty large quantities of vicious and corrosive liquids into the bay that tend to make the water more undesirable than the fire in some instances. Of this, however, we need not enter into details; the point is enough for the present, *i. e.*, merely to open up the many opinions that I sincerely hope will be given this subject before something definite is finally adopted.

As to the mechanical equipment and the manner of distribution, I would prefer the reciprocating three-plunger double or single acting pump with cranks set at 120 degrees one from the other, and of sufficient power and material to resist the heaviest work liable to be required, located in some permanent and convenient stationary shelter, adjacent to a fresh water supply, if possible, but the cleanest water available in any case. Several of the stations should be installed and all made tributary and auxiliary to one great system of mains and branches throughout the present fire district, with hydrants and mains of ample capacity and numbers to deliver 2 000 gal. per min. on any side of any single block in the district, at a pressure not less than 25 lb. per sq. in. at the lowest point. At all available points within the fire limits, as well as outside of them, there should be placed reservoirs and storage basins of 30 000 gallons or more where they do not interfere with the sewers and potable water systems, and at the junction of two or more streets, these basins to fill automatically, and to be used at every fire within the district, so that the water may be changed as often as practicable. These reservoirs are to be not more than 1 500 ft. apart in any direction.

The pumps should be driven by an explosive motor, perhaps a producer gas unit, so that it could be started at any time within from thirty to ninety seconds, and to be as far as possible independent of any other system or plant.

In the matter of local or auxiliary mains for distributing the water, should the street mains be destroyed, the pipe ought to be divided into units not to exceed 150 lb. in weight and not more than 20 ft. in length, with light and convenient bends for corners, and sections fitted with valves for attaching hose at least every block apart, or closer.

No attempt should be made to improve our present system unless an actual improvement is the result, and this should be so far above its present best condition and application that the public must be certain of protection against fire under the most extraordinary adversity or accident, and this I am afraid can be summed up in Mr. Richards' remark, " It is a hard problem."

Mr. Franklin Riffle. — Any effort to solve economically and effectively the problem discussed in this paper is deserving of serious consideration, especially when the author has the distinction of being an experienced and a successful engineer in the treatment of kindred problems. In view of San Francisco's recent disaster there can be no difference of opinion concerning the urgent need of an auxiliary system of fire protection for at least a considerable portion of what was formerly known as the business or down-town section of the city. The work of rebuilding this district has actively begun, and unless plans for a system that will admit of rapid and economical construction are adopted, and vigorously executed, we shall soon have a city of new buildings exposed to the same conditions of fire hazard as existed before. As Mr. Richards has pointed out, San Francisco is blessed with a never-failing supply of water, and all that is required to utilize it for quenching fire is to install, operate and maintain a system of pumps and pipes. The engineering features of such a system are comparatively simple, whether we adopt the system of fixed pipes supplied by gravity from a reservoir on Twin Peaks, that of fixed pipes supplied by direct pumping pressure, or that of portable pipes also supplied by direct pumping pressure, as discussed by the author. It is the opinion of the writer that any one of these three systems, if constructed in accordance with the best engineering practice, will furnish an effectual means of preventing conflagrations, although a careful analysis of each would no doubt show a wide difference in cost of installation, operation and maintenance, and probably, also, some difference in efficiency.

Of the three systems mentioned, the first (the reservoir system) is unquestionably the most expensive. Without having seen the plans now in course of preparation by the city administration, or even an estimate based on these plans, the writer does not feel that he is qualified to discuss fully this phase of the question. However, if we take into consideration the cost of the long supply main to the reservoir, the cost of the long main required to convey water from the reservoir to the distributing pipes in the congested district, and, finally, the cost of the reservoir, it would appear that the construction cost of such a system would vastly exceed that of a direct pressure system.

The direct pressure plan apparently combines all of the protective features of the reservoir system, and possesses the important economic feature of eliminating the construction and maintenance costs of the reservoir and long mains, together with

the operating cost of pumping water to an unnecessarily high elevation. For economic reasons, therefore (assuming that the two systems would be equally effective), there appears to be little or no justification for the present action of the municipal authorities in wasting valuable time elaborating plans and details for a system that will probably never be constructed, owing to its excessive cost. The writer predicts that the estimated cost of the reservoir system will be so high that the scheme will be abandoned as impracticable, in which case the direct pressure system will receive the attention it deserves.

Coming now to the portable pipe system proposed by the author, there can be no doubt of its low cost compared with a system of fixed pipes. In addition to this important advantage, it possesses one other of scarcely less importance, *i. e.*, the comparatively short time required to construct it. These two considerations should commend it, provided there is no doubt about its practicability or efficiency. Regarding its practicability, there would appear to be little chance for argument, but there may be a reasonable doubt concerning its efficiency when compared with a system of fixed pipes. The latter (in theory, at least) would be immediately available, while the portable system would always be attended with more or less delay before it could be made effective. The length of time required to take the pipes from their racks, and to distribute and connect them, might be a half hour, an hour, two hours, or longer, depending on circumstances, which no amount of human foresight could absolutely control. This delay might result in the destruction of much valuable property, which would be saved by a system that could be brought into immediate action. On the other hand, it is not improbable that the efficiency of the fire department employees would overcome this objection. It is a question that can be settled by no amount of theorizing. A practical efficiency test might quickly dispose of any and all objections. Some of our public-spirited citizens, who can spare the money, could not serve their city better than to arrange with Mr. Richards to construct an experimental plant in accordance with the general plan outlined in his paper.

There is no doubt in the mind of the writer that if the system under discussion had been in operation at the time of the recent disaster the fire department would have been able to save from destruction a large portion of the down-town section of the city.

Regarding the suggestion that fixed pipes are liable to be

disrupted and rendered useless by an earthquake of unusual intensity, the writer believes that if steel pipes are used, and special attention is given to their foundations, no fears need be entertained on this score. In those sections of the city where the water company's mains were damaged by the earthquake because of unstable foundations, it would be necessary to take exceptional precautions against rupture at the joints, either by preparing stable foundations by piling, or by using some form of flexible joints. It is true that this would add materially to the cost of construction, but in the light of our recent unfortunate experience, the plans for any fire protection system employing fixed pipes must be considered deficient unless adequate provisions are made for safeguarding the joints against rupture by a severe earthquake shock.

The writer heartily endorses the author's statement regarding the advisability of using higher velocities than are usually employed for the conveyance of water through pipes. The practice of adopting low velocities is uneconomical, since it frequently doubles the cost of a pipe line without apparently yielding any benefits that are in the least commensurate with the additional expense involved.

Although convinced of the feasibility of the author's proposed plan for additional fire protection, the writer would not be understood as advocating its adoption to the exclusion of fixed pipes. For reasons suggested above he believes the latter to be more efficient, although he is not prepared to state that the increased efficiency is worth the increased cost. Possibly a combination of fixed and portable pipes would assist to a great extent in disposing of the objections to each as an independent system. The pumping plants (these would be required for any one of the systems mentioned) and the portable pipes could be constructed and made available first, while the necessary fixed pipes could be installed later. Such a system would have the merit of affording additional fire protection at the earliest possible date, besides making it possible to omit many of the fixed mains that would be absolutely necessary in a single system of fixed pipes.

One thing is clear. Some definite plan of action should be decided upon at once and actively carried through to a finish, if the owners and occupants of the new buildings now being constructed and planned are to be given adequate fire protection and relief from burdensome insurance. If the same amount of effective energy could be injected into this project that is fre-

quently met with in private undertakings of similar magnitude, a satisfactory auxiliary fire protection system would be completed almost as speedily as a modern office building. And herein lies the real difficulty. The engineering difficulties to be overcome are small, indeed, when compared with the almost hopeless task of securing the requisite administrative initiative, without which nothing tangible can be accomplished. The people of San Francisco elected the present administration under the mistaken idea that it would be found capable of coping with such problems as this, but up to the present time its achievements have not been of such a nature as to give us the slightest encouragement to believe that the project under discussion will be handled with that intelligence and regard for the best interests of the city that the exigencies of the case demand.

Mr. Geo. W. Dickie. — This short suggestive paper by my friend, Mr. Richards, has interested me very much. Like him I lost the data that represented my life's work, and practically all the material things I had gathered during a busy professional life.

To many thinking men besides Mr. Richards the idea of using the sea water as a means of extinguishing fires has presented itself, and in several cities partial systems have been installed, but nowhere has any attempt been made to lay a pipe line immediately on an alarm of fire within the limits that such a system could reach. Mr. Richards admits that the problem is not an easy one, and I doubt if an 8-in. pipe could be laid at the rate of half a mile in thirty minutes. Such pipe, in 50-ft. lengths, and to stand the pressure required, would weight about 1 000 lb. each length. This would not be very easily handled, although I think automatic locking joints could be designed to be depended upon. There would be no difficulty about the pump barge or the pumps, but the transportation of the pipe and laying of it present the greatest difficulty. To be effective the radius of action would have to be at least one mile. This would be 106 lengths of 50 ft. If these were all ready and loaded on special automobile cars, each carrying 10 lengths, with means of handling them, the load on each would be 5 tons. The barge would carry these cars loaded and ready and with an apron long enough to run them on to any wharf by having proper starting marks.

The laying of the pipe could proceed at ten different points, each section joined by a flexible part. I think by some such device it might be possible to reach a fire in the heart of San Francisco from the bay inside of an hour from the alarm.

In the meantime, of course, the usual methods of fighting a fire at the beginning would be in operation.

It is difficult to foretell what degree of expertness could be reached in pipe laying, and I think that it might be a matter of astonishment to even those best able to judge what regular practice can achieve.

Mr. Richards may be well on the safe side in saying that half a mile of 8-in. pipe could be laid in half an hour. The subject certainly is one well worth a careful study.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1907, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

George Henry Evans.

MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

THE Technical Society of the Pacific Coast has lost one of its old members, one who, although not a frequent visitor, had been a life member for many years.

George Henry Evans died at Berkeley, Cal., on February 4, 1907. He was taken suddenly ill and an operation on the gall bladder resulted fatally. His death has caused widespread regret in San Francisco, where he had a large number of friends. Born in Hull, in England, forty-one years ago, he was a mining engineer in active and successful practice. His specialty was placer mining. He was the inventor of the Evans hydraulic elevator now used in most hydraulic mining where the elevation of gravel is necessary. He was a member of the North of England Institute of Mining and Mechanical Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the Technical Society of the Pacific Coast and the Franklin Institute. He was also a member of the Bohemian Club of San Francisco, where he had a wide circle of friends. He leaves a widow, son and daughter. He came to California ten years ago to take charge of the operations on the Golden Feather Channel, at Oroville, succeeding Colonel Frank McLoughlin as manager. This position he held for three years, until he became manager of the Banner Mine, also in Butte County. Subsequently he traveled widely, becoming consulting engineer of various alluvial enterprises in Colorado, California and elsewhere. He was one of the consulting engineers associated with the Risdon Iron Works. As a member of several engineering societies he had a wide acquaintance, among whom his kindly disposition and cultivated manner made him always welcome. The engineering profession has lost a worthy member.

The Society was apprised of the sudden death of Mr. Evans, and the above data were sent through the courtesy of Mr. A. S. Moore to the Secretary.

OTTO VON GELDERN.

OBITUARY.

William Winslow Burnham.

Member of the Sanitary Section of the Boston Society of Civil Engineers.

William Winslow Burnham was born in Biddeford, Me., August 24, 1875, the son of Francis M. and Abby M. Burnham. He received his early education in the public schools at Biddeford, but owing to his father's death when he was twelve years old he was obliged to leave school, and was employed in a stationery store. While carrying on this work he prepared himself for Bowdoin College, but as his tastes were more along engineering lines he entered the Massachusetts Institute of Technology in 1899, graduating from the sanitary engineering course in 1903.

Immediately after graduation he took a position as assistant in the engineering department of the Massachusetts State Board of Health. In June, 1904, he accepted a position with the United States Geological Survey as hydrographic aid, which position he held until February, 1905. His work here was the determination of the depth and character of the ground water in the Nevada desert known as the "Carson Sink" and an investigation of the character of the surface and ground waters of Georgia.

In February, 1905, he entered the employ of the Hugh MacRae Company, of Wilmington, N. C., which position he held until his death. His work with this firm was in connection with the irrigation and drainage of large tracts of land in North Carolina.

Mr. Burnham married Miss Ella M. Cate, of Malden, Mass., March 6, 1906. He was taken ill with typhoid fever June 23 and died August 11, 1906. He was a member of the Sanitary Section of the Boston Society of Civil Engineers and of the New England Water Works Association.

Elbert E. Lochridge.
William S. Johnson.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVIII. MAY, 1907. No. 5.

GAS ENGINEERING.

BY W. A. BAEHR, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, March 20, 1907.]

Mr. President and Gentlemen,—When I was first requested to read a paper before the Engineers' Club of St. Louis it was with the understanding that I might select any subject provided it was connected or related to the gas business. This appealed to me as an opportunity to open a discussion on some particularly interesting branch of our work, but on second thought it appeared to be more desirable to cover the field in a general way and for various reasons. Among these might be mentioned the idea of securing greater interest among the engineering profession at large than would be obtained by a purely technical paper, and further of adding my mite towards the better understanding of the general features of the gas business by people not connected with it.

It is difficult at present to assign a good reason why the gas business should be considered mysterious in any way since in all companies with whom I have been associated it has been the invariable custom to welcome visitors to the works and shops, and to carefully explain all the steps in the processes of manufacture and distribution, as it is believed that a broad, liberal and open policy is superior and more conducive to the good will of the public than the old idea of concealment.

GAS ENGINEERING.

It is rather difficult to define gas engineering. During the reading of this paper it will develop that a gas engineer has

need of civil, mechanical, electrical, and chemical knowledge, and I will therefore leave the definition of this profession to crystallize in your minds during its progress.

Division of Subject.

It would be wholly beyond the scope of a paper such as this to endeavor to include even a general consideration of the economic geology and chemical technology of the materials for gas manufacture. I will therefore omit these subjects entirely, and will pass on to the two great divisions of the gas business, viz., natural gas and artificial gas.

Natural Gas.

This again is a subject which I will not endeavor to cover except in a skeleton outline. Since natural gas is found in nature, man takes it as he finds it, and the methods in use for its distribution differ from those I will describe later only in the point that usually much higher pressures are employed in transmitting it from the fields to the centers of consumption than are in use for transmitting artificial gas. The question of the origin of natural gas fields, collection, wells and well machinery, methods of controlling wells, their location, arrangement and operation, transmission, questions of pumping plants, etc., form ample material for a separate paper. Natural gas is an important economic factor among the industries of our country, but suffice it to say that it is largely composed of methane, or CH_4, and has a high thermal value, usually from 900 to 1 000 B.t.u. per cubic foot when burned in air. It is usually gathered from the various gas wells in a district by means of comparatively small screw pipes, which terminate in a common large header, which leads to the centers of consumption. If the line is not too long, and the pressure is sufficient, the transmission system is a simple pipe line. If other conditions exist it may be necessary to install one or more compressing stations along the line. At the points of consumption the line pressure is reduced through governors into a secondary low-pressure system, or by individual governors directly to each consumer.

Artificial Gas.

We naturally divide gas engineering into two parts: Manufacture and distribution. The former embraces all the steps from the crude to the finished product, while the latter takes the gas from the outlet of the works and leads it through various paths and apparatus to the consumer's burner.

Manufacture.

Under this heading, and stated in the order of their importance, we can group the production of the following kinds of artificial gases:

1. Coal gas.
2. Water gas.
3. By-product coke oven gas, such ovens being distinguished from the bee-hive type.
4. Producer gas.
5. Oil and Pintsch gas, — Lowe oil gas.
6. Blast-furnace gas.
7. Acetylene.
8. Gasoline air gas.
9. Miscellaneous, such as resin gas, wood gas, hydrogen-methane gas, garbage gas, CO_2 gas, etc.

Taking these up in order we will first consider the manufacture of

Coal Gas.

This art is over a century old. William Murdoch, in England, between the years 1792 and 1798, was engaged in experimenting with different coals and in devising apparatus for their distillation. In 1797–8 lighting by coal gas became an accomplished fact, for Murdoch by means of his experimental plant first lighted up his dwelling house, and a short time later a considerably larger building at Birmingham.

From these first attempts, coal gas manufacture has successively progressed up to the present time.

The coal used for gas-making purposes is mostly of the caking bituminous variety. In England and on the continent some cannel coal is used, and non-caking or even lignite coal can be made to yield gas.

These latter two varieties do not give the requisite quantity or quality of gas, nor do they yield any valuable by-products except some tar and ammonia. It has been found by repeated tests that it is best to use lump coal in preference to mine run or slack on account of increased gas yield and better resulting coke.

For the successful carrying on of coal-gas manufacture, the fact that the gas works must run day and night and all the year round makes it necessary to have a large coal stock on hand all the time. Furthermore, plants which receive their major portion of coal by water, such being usually the cheaper method of transportation, are limited to a certain portion of the year during

which the water transportation facilities are available. Thus a large stock of coal is bound to accumulate, and I can best illustrate this by stating the storage capacity of a few prominent coal-gas works.

	Population.	Coal Storage Capacity.	
Denver (all-rail delivery)	150 000	10 000	tons
Milwaukee	300 000	125 000	,,
St. Louis (old works)	700 000	150 000	,,
St. Louis (new works)	probably	500 000	,,

At $3.00 per ton you can readily see the immense amount of money tied up in coal stock at certain times of the year.

In modern works the coal is handled by the most approved machinery, and in some plants hand labor is practically eliminated.

The distillation of coal is now carried on in clay retorts, usually of a horizontal " D " section. Formerly cast-iron retorts were used, but these would not stand the high heats necessary to drive all the gas out of the coal.

The average size of the horizontal retort in use to-day is probably 16 in. by 26 in. in cross section by about 9 ft. long inside. Such a retort will distill 2 000 lb. of coal per day in six charges, thus taking 4 hr. to burn off one charge. In very recent installations single retorts take as high as 800 lb. of coal in one charge, and the figure is constantly growing.

In most works the retorts are open only at one end, but they are also made with both ends open and are then called " through retorts." These present an important advantage, inasmuch as the coke can be pushed out of them by a comparatively simple discharging machine, which at the same time is readily arranged to also act as a charging machine. In those plants where the retorts are open at one end only, the charging and discharging machinery become more complex.

It is an open question to-day among prominent gas engineers as to whether machine-operated horizontal, vertical or inclined retorts are best. The new Milwaukee gas works is designed with horizontal retorts operated entirely by machinery, and Mr. Brown, engineer of the Milwaukee Gas Light Company, states they figured a saving of $30 000 per year over inclines. It is undeniably true, however, that inclines are used largely abroad, and some new installations are being erected in this country. Retorts for inclined benches are sometimes as much as 20 ft. long, and carbonize a great deal of coal per day. They are usually operated entirely by machinery, and the usual inclination is from 32 degrees to 33 degrees from the horizontal.

Right here it is well to note that the present day is witnessing the evolution of the so-called vertical retort setting. In these schemes the fundamental idea is to use a vertical retort, drop the coal in at the top and extract the coke from the bottom either by continuous or intermittent operations. These settings are being developed extensively abroad, the most notable being the Woodall-Duckham and Settle-Padfield systems in England, and Dr. Bueb's system in Dessau, Germany. It is probably safe to say that the *idea* of the vertical is good, and these systems give promise of good results, but it is equally safe to take the position that they are still in a crude state, and that some years will probably elapse before we shall witness a completely developed system of this type which will be as satisfactory and sure in operation as the present-day horizontals operated by machinery.

The number of retorts per bench varies from one to ten or more. In settings of two retorts per bench the arrangement is either one alongside the other, or one over the other. Where there are three, usually there is a lower tier of two retorts with one over them.

With four retorts per bench the usual design is to place them in two vertical rows of two each. With five, the arrangement is similar to four, except there being a fifth retort between the two vertical rows of twos.

We may well call a bench of sixes, or six retorts per bench, the most common and widespread arrangement. Here the retorts are arranged in two vertical rows of threes, and this bench has long been a favorite one among gas men on account of its ease of regulation and simplicity of construction.

Formerly benches of eight were built with two outside vertical rows of three retorts each, and one vertical row of twos in the center. This gave rise to a very wide retaining arch, and in order to obtain the advantages of the style of construction and of operation of the sixes, foreign engineers designed a type known as vertical eights. In this design there are two vertical rows of four retorts each, and you can readily see that the retaining arch is narrowed to practically the same width as for a bench of sixes.

The first objection to these vertical eights was that the upper rows of retorts were so high above the operating floor that they could not be charged by hand. Later improvements in drawing and charging machines have made mechanical operations so certain and cheap that the objection as to height disappears.

Benches of nines are built with three vertical rows of three retorts each, and benches of tens with two vertical rows of fives. The types can be extended almost indefinitely.

Leaving the upper portions of the benches we will now consider the lower or fire-containing part. Here is the really interesting portion of bench work, and we can divide the various types into the following general classes, viz., isolated generators, and those having one generator or furnace for each bench.

By an isolated generator we mean a gas producer set in a place by itself, away from the stack of benches, and generating a producer gas which is conducted to the benches and burned around the retorts. The success of this type of construction is dependent somewhat upon the nearness of the producer to the benches, as the gas must not be allowed to cool during its passage. There is an important advantage in isolated generators, inasmuch as one such producer can serve several benches, and thus by means of dampers the heat in each bench can be closely regulated.

Isolated generators are used somewhat abroad, but have made no headway in this country. I believe there is a great possibility of their being further developed, and especially so as they offer such excellent facilities for recuperation being carried to its limit, even if iron recuperators are necessary, clay being the style now used.

In the other type, where each bench has its own furnace or generator, the division of design is very pronounced, and is based on fundamental principles of thermo-chemistry. We divide such benches into the following kinds:

1. Direct-fired benches.
2. Half-depth recuperative benches.
3. Full-depth recuperative benches.

A direct-fired bench is one in which the air for combustion is drawn directly under the fire, and in which the carbon burns directly to CO_2, according to the equation, $C + O_2 = CO_2$.

The retorts are thus heated like an ordinary steam boiler by the passage of the hot products of combustion around them and by the heat radiated from the fire.

Each pound of carbon in burning to CO_2 thus produces 14 544 B.t.u.

Theoretically, 11.54 lb. of air are required to burn one pound of carbon to CO_2, assuming that air consists of 23 parts by weight of oxygen, and 77 parts by weight of nitrogen. Theoretically, then, the flame temperature of C burning to CO_2, assuming constant specific heats for the gases at all temperatures for ease of calculation, is as follows:

$$\frac{14\ 544}{\underset{(CO_2\ \times\ \text{sp.ht.}\ +\ N\ \times\ \text{sp.ht.})}{3.66 \times 0.2164 + 8.88 \times 0.244}}$$

$$= \frac{14\ 544}{0.792 + 2.167}$$

$$= \frac{14\ 544}{2.959} = 4915 \text{ degrees fahr.}$$

I wish to explain right here that I am satisfied that the specific heat of gases increases with increase in temperature, but for the purposes of this lecture it would only result in confusion were I to attempt to use such calculations, and I therefore use constant values so your minds may be kept clearer concerning the relations of the various parts of the art.

As a matter of interest I here insert a table on the specific heats at various temperatures of H_2O, CO_2, CO, N_2, O_2 and H_2, as determined by Dr. H. B. Harrop, who based this table on all the data he could gather in this country and Europe. It shows how erroneous our ordinary heat calculations are, even though this table be somewhat modified by subsequent investigators. At any rate they are the best data available on this subject of which I have knowledge, and having made some efforts personally to gather similar information, I am glad to accord thanks to Dr. Harrop for his work.

Fahrenheit.	H_2O.	CO_2.	CO & N_2.	O_2.	H_2
32		0.182	0.238	0.208	3.36
212	0.360	0.201	0.242	0.212	3.42
250	0.408	0.204	0.243	0.213	3.435
300	0.445	0.209	0.244	0.214	3.452
350	0.480	0.214	0.245	0.215	3.469
400	0.504	0.218	0.246	0.216	3.486
450	0.522	0.223	0.247	0.217	3.503
500	0.536	0.228	0.249	0.218	3.520
600	0.563	0.237	0.252	0.220	3.554
700	0.587	0.246	0.255	0.222	3.588
800	0.609	0.255	0.258	0.224	3.622
900	0.625	0.263	0.260	0.226	3.656
1000	0.641	0.270	0.262	0.228	3.690
1100	0.655	0.277	0.264	0.230	3.724
1200	0.670	0.283	0.267	0.232	3.758
1300	0.685	0.289	0.269	0.234	3.792
1400	0.699	0.295	0.272	0.236	3.826
1500	0.712	0.300	0.275	0.238	3.860
1600	0.723	0.306	0.278	0.240	3.894
1700	0.734	0.312	0.280	0.242	3.928

Fahrenheit.	H_2O.	CO_2.	CO & N_2.	O_2.	H_2.
1800	0.745	0.317	0.282	0.244	3.962
1900	0.758	0.322	0.284	0.246	3.996
2000	0.769	0.327	0.286	0.248	4.030
2100	0.778	0.332	0.288	0.250	4.064
2200	0.787	0.337	0.290	0.252	4.098
2300	0.794	0.341	0.293	0.254	4.132
2400	0.802	0.345	0.296	0.256	4.166
2500	0.809	0.349	0.299	0.258	4.200
2600	0.817	0.353	0.301	0.260	4.234
2700	0.823	0.357	0.303	0.262	4.268
2800	0.829	0.361	0.305	0.264	4.302
2900	0.835	0.365	0.308	0.266	4.336
3000	0.838	0.368	0.310	0.268	4.370
3100	0.841	0.371	0.313	0.270	4.404
3200	0.845	0.374	0.316	0.272	4.438
3300	0.849	0.377	0.319	0.274	4.472
3400	0.854	0.380	0.321	0.276	4.506
3500	0.859	0.383	0.323	0.278	4.540

The above table gives the mean specific heats, at constant pressure, in B.t.u. per lb. of gas as extracted from discussion by Dr. Harrop in *Journal of Gas Lighting*, March 20 and 27, 1906.

In this paper, however, I will use the following heats of combustion:

C to CO_2 = 14 544 B.t.u.
C to CO = 4 400 B.t.u.
CO to CO_2 = 4 348 B.t.u.

Also the following specific heats:

CO_2	0.2164
N	0.244
Air	0.2379
H_2O vapor	0.48

Now the losses which occur in a direct-fired bench are due to several causes, as follows:

1. To over ventilation of fires.
2. To loss of heat in flue gases.
3. To other losses by clinkering, radiation, opening of doors, etc., all of which I will call the X losses.

Concerning the first class of losses, it is well known that in practical direct firing it is impossible to get along without using considerably more than 11.54 pounds of air per pound of carbon. Therefore, the flame temperature is reduced by just the proportion of excess oxygen and nitrogen heated from atmospheric temperature to the temperature of the escaping waste gases.

The second class of losses, or the sensible heat carried away by the flue gases, is due to the fact that in direct bench firing there is no way to keep the stack temperature below about 1 500 degrees fahr., thus wasting all the sensible heat of these gases from a temperature of half the above up. I am glad to say that direct-fixed benches are becoming rare.

Before passing to the second great class of benches it is necessary that you fully comprehend the difference between the terms recuperative and regenerative.

A recuperative bench is one in which both the primary and secondary air, or the secondary air only, are preheated by passing through a flue, or set of flues, without reversal in direction, and continuously the transfer of heat being accompanied *through* the walls of the flues.

Now a regenerative bench would have its primary and secondary air preheated by passing intermittently through a set of flues which are also intermittently heated by the passage of the waste gases. The point is that the transfer of heat is not accomplished *through* the walls of the flues, but by contact on the same surfaces as were touched by the waste gases.

In the ordinary coal gas construction regenerative benches are not used at all, but in some forms of by-product coke ovens they are used. Bearing in mind then that recuperative benches are those used, we can easily define half-depth and full-depth benches as follows:

A half-depth recuperative bench is one in which the secondary air only is preheated, whereas in a full-depth bench both the primary and secondary air are preheated.

With these definitions I can now proceed to explain modern gaseous firing. This consists of a deep furnace below the bench in which the carbon is first converted into CO_2 in the lower layers of the fuel bed, and this CO_2 on passing up through the incandescent carbon decomposes to CO. The air which is admitted below the fire is called primary air.

The CO from the fuel bed passes up through the furnace arch opening and meets the secondary air, which has been preheated by passing in through the recuperators, and surrounding the retorts is the combustion chamber, and here the CO burns to CO_2.

Now, when the water is admitted below the fire in the ash pan it vaporizes, and in passing through the fire decomposes into H and O. The oxygen first unites with C to form CO_2 and this in turn decomposes to CO. Thus the gas issuing from the fur-

nace contains N, CO and H. The H in the combustion chamber immediately burns to H_2O vapor again. The water in the ash pan is used to aid in preventing clinkering and I will now explain a new rational method of clinker prevention which I think will appeal to all.

Clinkers form because when a fire burns too rapidly a high local temperature is produced, and the ash fuses. Now in gaseous firing we burn the carbon to CO_2 in the bottom of the fuel bed and form clinkers. By passing H_2O vapor up with the primary air as soon as this vapor comes in contact with the hot spots it is decomposed. The decomposition is an endothermic reaction; that is, heat is absorbed and thus clinkers prevented.

Again in gaseous firing we aim to produce CO in the generator and do it by forming CO_2 in the bottom of the fire. Now, when CO_2 decomposes to CO, the reaction is also endothermic; consequently the point is, Why can we not introduce CO_2 below the fire; in other words, get just what we want there, and then, by having the aforesaid endothermic reaction taking place, prevent the ash from fusing? This is exactly what we can do, and our old friend Siemens, of regenerative furnace fame, did the same thing. He derived his CO_2 from the waste gases, but he introduced it by means of a steam jet and defeated the very object he was after. He put his fire out. However, this CO_2 with the waste gases can be introduced by means of air jets, blowers or other devices.

You see we do not wish to use water under the fire because the high specific heat of H_2O vapor causes too many B.t.u. to be carried out of the chimney with the waste gases. I regard this use of CO_2 of the waste gases as one of the most important advances of gaseous firing of modern times, as by preventing clinkers we can run gas producers at extremely high tension, that is, under heavy blast pressure.

Before leaving the subject of recuperative benches I will state that gaseous firing has several great advantages over direct firing, among which are the following:

1. The excess of air per pound of carbon is reduced to a minimum.

2. The recuperation enables us to recover a large part of the sensible heat of the waste gases.

3. Regulation is rendered easy.

4. Wear on benches is greatly reduced.

5. There is a great saving in operating expense.

To show the comparative theoretical thermal efficiency of a half-depth and a full-depth bench I will give the following calculation. The temperatures in different portions of a bench were determined by means of a Le Chatelier pyrometer and are as follows:

Temperature	just above fire	2000	degrees fahr.
,,	in combustion chamber	2500	,,
,,	waste gases, top of recuperator	1500	,,
,,	waste gases, bottom of recuperator	750	,,

For full-depth bench:

Heat Produced.

1 lb. of C with 2.66 lb. O and 8.88 lb. N. to 3.66 lb. CO_2 and 8.88 lb. N . . . . 14 544 B.t.u.

Losses.

3.66 lb. CO_2 from 60 degrees to 2500 degrees fahr. = $3.66 \times 0.2164 \times 2440$ . . . . 1 932 B.t.u.

8.88 lb. N from 60 degrees to 2500 degrees fahr. = $8.88 \times 0.244 \times 2440$ . . . . 5 287 B.t.u.

Gross loss . 7 219 B.t.u.

Recovered by absorption in secondary air, which would be,

$$5.77 \times 0.2379 \times 2440 = 3\,349 \text{ B.t.u.}$$

The flue gases would have a specific heat of 0.236 and the temperature of the escaping gases at the bottom of the flues where secondary air is admitted would be,

$$2500 \text{ (degrees)} - \frac{5.77 \times 0.2379 \times 2440}{12.54 \times 0.236} = 2500 \text{ degrees} - \frac{3\,349}{2.959}$$
$$= 2500 \text{ degrees} - 1132 \text{ degrees} = 1368 \text{ degrees fahr.}$$

Then the heat recovered by absorption in the primary air would be

$$5.77 \times 0.2379 \times (1\,368 - 60) = 1\,795 \text{ B.t.u.}$$

The final temperature of the escaping gases would be,

$$1368 \text{ degrees} - \frac{5.77 \times 0.2379 \times (1\,368 - 60)}{12.54 \times 0.236}$$
$$= 1368 \text{ degrees} - \frac{1795}{2.959} = 1368 \text{ degrees} - 606 \text{ degrees} = 762 \text{ deg. fahr.}$$

Then the net loss of heat = 7 219 — (3 349 — 1 795) = 2 075 B.t.u.

Therefore the theoretical thermal efficiency of a full-depth bench, not allowing for radiation, opening of doors, etc., would be

$$(14\,544 - 2\,075) \div 14\,544 = 85.73 \text{ per cent.}$$

For a half-depth bench the heat produced and the gross losses are the same as for a full-depth bench, as is also the heat recovered by absorption in the secondary air. But there would be no recovery in the primary air, and therefore the net loss for a half-depth bench would be,

$$7\,219 - 3\,349 = 3\,870 \text{ B.t.u.}$$

The theoretical thermal efficiency, with previously mentioned omissions, for a half-depth bench would then be

$$(14\,544 - 3\,870) \div 14\,544 = 73.39 \text{ per cent.}$$

In operating any kind of a furnace I will add that there is only one way to do so correctly, and that is by flue gas analysis. We usually determine the percentage by weight of CO_2, O, CO and N. Knowing that air consists of very nearly 23 parts of O and 77 parts of N by weight, we know that this relation of O and N must be maintained in all the flue gases.

Before leaving the subject of coal gas manufacture I will add that a typical composition of coal gas is as below in per cent. by volume.

CO_2	1.5
CO	7.0
O	0.5
Illuminants	7.0
CH_4	34.0
H	46.0
N	4.0
	100.0

We will next consider the manufacture of

Water Gas.

Water gas was experimented with and virtually invented by Tessie du Motay, a Frenchman, in about 1865, but Professor Lowe in America practically perfected the apparatus that bears his name about the same time.

I can only take a few moments to explain the operation of a modern Lowe water gas set. There have been many forms of water gas apparatus, but that named above is the one most widely used now. Such a set consists of,

First. A generator, or vessel built of an iron shell, with a firebrick lining, and containing a deep bed of incandescent fuel.

Second. A carburetter, or vessel consisting of an iron shell, lined with firebrick, and filled with a checker work of firebrick. This vessel has an open chamber near the top into which the oil is sprayed.

Third. A superheater, or vessel built similar to the carburetor, but without the oil chamber.

To explain the operation of such a set we will first assume it cold, but with a coke or anthracite fire started in the generator. By means of a fan blower a blast is turned under this fire, and the carbon in the lower portion burns directly to CO_2. This on passing up through the fuel bed is wholly or partly decomposed into CO, the amount depending largely upon the velocity of the blast. In the Delwick process this blast velocity is high and the fuel bed is shallow, so that the carbon is kept in the form of CO_2.

When the producer gas (for such it is) reaches the top of the generator above the fire it consists of principally N, CO and some CO_2. By means of a large firebrick-lined connection this mixture is conducted to the top of the carburetor. Here an additional blast opening introduces fresh air, and a portion of the CO in the producer gas burns to CO_2 in the carburetor. The resulting mixture passes out of the carburetor and into the bottom of the superheater, where still another blast admits enough air to burn the remaining CO to CO_2. The final waste gases then pass out of the stack valve at the top of the superheater and escape into the atmosphere, or pass through a Green economizer or other contrivance to heat feed water, or for other purposes. The process of blasting, or blowing, is continued until the entire fuel bed in the generator is at a white heat, the carburetor being then full of a checkerwork of firebrick at a glowing red heat, and the superheater at a slightly lower color than the carburetor. The set is now ready to make gas.

The blast is first shut off all the vessels, and the stack valve on top of the superheater is closed. Then live steam is turned into the generator below the fire. The resulting reactions are very instructive. The H_2O is first decomposed by the incandescent heat to H and O. This reaction is endothermic, that is, heat is absorbed in doing that work. The hydrogen passes up through the fire unchanged.

The oxygen on the other hand immediately combines with carbon to form CO_2, and every pound of carbon thus burning

delivers 14 544 B.t.u., the reaction being exothermic. The CO_2, however, on passing upwards through the fire, decomposes into CO with an endothermic reaction, and this CO appears on top of the fire mechanically mixed with the hydrogen. This mixture is the so-called blue gas, or uncarbureted water gas, and is merely one form of producer gas, having a calorific value of about 350 B.t.u. per cubic foot.

You will note that the reactions in the generator are mostly endothermic, and in fact the fire is cooled very rapidly under the admission of the steam, a run generally being from 7 to 10 min., at the end of which time it is necessary to blast up again.

Coming back to the blue gas, so called because it burns with a blue flame in the air, we find it passing into the top of the carburetor. Here it meets with a spray of oil. This is sometimes the crude oil, but more often a gas distillate, which is obtained from crude oil after distilling off the gasolines and kerosenes, and before the heavier lubricating oils appear. The fraction coming off between these two extremes is neither fit for illuminating nor lubricating purposes, but is simply a fuel oil, excellent for boiler use, but I believe is now mostly directed towards making gas.

This oil, on coming into the top chamber of the carburetor, vaporizes under the intense heat, and mixing with the blue gas starts down through the carburetor. The lower portion of the carburetor and the entire superheater are merely heated checker work for the purpose of "fixing" the gas. By the term "fixing" we mean to render permanent under ordinary conditions. It has been found that oil or coal gas, if not subjected to sufficient heat, on coming to atmospheric temperature partially condenses into liquid hydrocarbons, and it is to render these hydrocarbons permanently gaseous that "fixing" chambers are employed. This of course involves a change of the hydrocarbons into different series and components of series.

The practical result of adding the oil is to make carbureted water gas, which is luminous and of higher calorific value than the blue gas. The average heat value is from 600 to 650 B.t.u. per cubic foot, and it can be made up to 35 or even 40 c-p. although that is beyond the customary limit, which is about 23 to 25 candles.

When the set has been making gas for a certain number of minutes, it becomes too cool for economical operation. The oil is then shut off, next the steam and then the stack valve is opened. Thereupon the blast is turned under the fire and the whole operation is begun over again.

On account of the steam striking the under side of the fire and cooling it too rapidly it is now customary to make a so-called "down run" every second or third time. This simply means that the steam passes down through the fire, the connections on the machines being arranged so as to permit this. As often as the fire requires it, fresh coke or coal is admitted into the generator, the ashes and clinkers being taken out at the bottom.

In places where anthracite is reasonably cheap it is used, but probably the large majority of plants use oven or gas coke. Bituminous coal can be mixed with the coke, or even a small proportion of lignite, but the latter does not work well.

In order to give you an idea of the capacity of a water gas set, I will say that an 8 ft. 6 in. set, with a grate area of 30 sq. ft., has a capacity of, roughly, 25 000 cu. ft. of gas per square foot of grate. An 11-ft. set in St. Louis operating on gas coke can produce, roughly, 35 000 cu. ft. of gas per square foot of grate area, or with anthracite coal as high as 42 000 cu. ft., all per day of 24 hr.

As I wish to take up the treatment of gases as a separate subject a little later on, we will now pass to the manufacture of

By-Product Coke Oven Gas.

By-product coke ovens are an outgrowth of a desire to secure an economical arrangement of apparatus to utilize the gas, tar, ammonia and cyanogen produced while manufacturing coke, at the same time not reducing the quality of the coke produced from that obtained from beehive ovens. They were first in evidence in steel plants, and the industry is represented in the United States by the United Coke and Gas Company, and the Semet-Solvay Company.

By-product coke ovens not only affect the gas industry by producing gas, but they contribute large quantities of coke, tar and ammonia to the market. These ovens are nothing more or less than sets of large built-up retorts. Approximately the first 40 per cent. of the coal gas given off is sold as illuminating gas, as it is the richer portion, the remainder of about 60 per cent. being used to heat the retorts, and this 60 per cent. is of a low photometrical and calorific value. The operation of such ovens is not very different from a large modern gas plant, except the much larger scale upon which it is carried out. The very magnitude renders mechanical devices for handling everything absolutely necessary.

I do not wish to dwell long upon any of the gas manufacturing processes except coal and water gas, and will therefore con-

fine my description by illustrating the size of a by-product coke oven plant with whose design I am associated.

This plant is to consist of 400 Semet-Solvay or Otto-Hoffman ovens, erected in eight stacks of 50 retorts, or ovens, each. It will use, per day of 24 hr., 3 000 tons of coal. The products will be about

1 700 tons of coke per day.
40 000 gal. of coal tar per day.
15 000 lb. of anhydrous ammonia or
60 000 lb. of ammonium sulphate per day.

I will leave it to you to construct, in your minds, the machinery necessary to perform all this.

In connection with the subject of by-product coke ovens I take this opportunity of emphasizing the advantages of these plants as an aid in the great problem of smoke prevention. As you know, there has been considerable agitation in St. Louis for the abatement of the smoke nuisance. The increase in the use of gas and of coke instead of soft coal wherever a solid fuel is required, is certainly a step in the right direction.

The coke from a by-product coke plant would be available for the small and carelessly operated boiler plants which are the chief sinners at present, and also for domestic heating furnaces, and for other uses to which gas has not yet been applied. Coke, being a smokeless fuel, and available at moderate cost, would offer the means for more easily enforcing the legal restraints of smoke production.

Producer Gas.

This gas is usually made by one or both processes already explained under coal gas and water gas manufacture. It sometimes consists of CO and N produced by air being blown through a bed of incandescent fuel, and is then possessed of a heat value of about 140 B. t. u. per cubic foot. If in addition to the blasting process we add steam under the fire, the resultant gas will contain H, CO and N, as previously explained. Of course there are always some impurities as CO_2, H_2S, etc., associated, but I am naming only the principal constituents.

Producer gas is coming into prominence of late owing to great advances in the design of gas engines, and those interested can secure much pleasure and benefit from studying up such processes as the Mond, Dowson, Duff, Wood, Morgan, etc.

Oil and Pintsch Gas.

Since Pintsch gas is a pure oil gas I will describe it. Such a gas is usually used where a high candle-power is necessary, and

in the Pintsch gas system it must stand comparatively high compression without liquefaction of too large a part of it. The average coal gas made is probably 16 c-p. in this country; but in England and Europe the poor grades of coal obtainable will produce gas of only from 8 to 14 candles. It was formerly the practice to enrich coal gas by the addition of oil gas, but the water gas process is doing away with that.

In the Pintsch system we have probably the largest application of pure oil gas there is in vogue. The process is to distill and gasify the oil in iron or clay retorts very much as coal gas is produced, but with this difference, — the oil is run into the retorts constantly in a small stream, and they are opened only for cleaning out and decarbonizing.

Under coal gas manufacture I should have added that retorts periodically carbon up, that is, the heat of the retorts breaks up some of the hydrocarbons formed during distillation and carbon deposits on the sides and bottom of them. This carbon deposit is very dense and hard, and is removed by burning it off the walls of the retorts. You have all seen this substance, for it is used largely to manufacture electric arc light carbon.

Now in oil gas the same thing occurs, and were it not for carbon and tar deposits an oil retort might be used indefinitely. Pintsch gas is of about 60 c-p., and after purification is compressed to from 10 to 20 atmospheres and is thus stored in strong tanks under railroad cars, where it is used for lighting. Our Pintsch plant in St. Louis has 400 000 cu. ft. daily capacity, and can gas 1 200 to 1 400 cars daily. This plant is one of the largest of its kind in the world, and was practically taxed to its capacity during the World's Fair.

Lowe Oil Gas.

There is one other noteworthy application of oil for gas-making purposes, and that is the Lowe oil process. This consists of an apparatus similar to a water-gas set. To heat it, oil is burned with air directly in the generator and superheater. These vessels are filled with a checkerwork of firebrick, which heats up to a bright red under the hot oil fire. When the heat is up, the air is cut off and the oil is admitted alone. This vaporizes and gasifies the oil, which gas is afterwards mixed with air to reduce the candle-power to a reasonable commercial basis, say 20 candles.

You can readily see that such a process is only applicable where oil is plenty and cheap. Both it and the Pintsch system require about 15 gal. of oil per thousand cubic feet of gas

made. If oil were 4 or 5 cents per gallon, the common Eastern price, the Lowe gas would thus cost 60 cents per thousand for oil alone. In fact the Lowe oil gas process is used only in or about California, where immense deposits of oil are found, and where it is worth possibly 1 or 2 cents per gallon.

Blast-Furnace Gas.

This subject is not really in the realm of gas manufacture and I will only touch upon it. It is a very low calorific gas, of only about 90 B.t.u. per cubic foot, but is being largely used to drive gas engines, some engineering experts being of the opinion that it is the best available gas for such use on account of its readily withstanding high compression. This brings us to a short consideration of the final classes of gas I will touch upon, viz.:

Acetylene, Gasoline Air Gas and Miscellaneous Gases.

Acetylene, or C_2H_2, is produced by the action of water on calcium carbide. It is a very heavy gas, of high candle-power, and its flame is said to most nearly resemble sunlight in its spectrum, that is, more than any other artificial light. Even though such water-power developments as Niagara and the Sault have rendered the production of calcium carbide reasonably cheap, acetylene is still too dear for general use. For lighting country residences, etc., it finds a limited application, and can be adapted to fuel use if desired.

Wood gas can be made by distilling wood either in horizontal or vertical retorts. A fair grade of coke is produced therefrom, and this process is applied in France and other foreign countries where coal is scarce. This, and garbage gas made by distilling garbage, with many other minor processes, finds a limited application.

I will now pass to the head of

Purification.

Coal Gas. In this gas we extract first the tar, then the ammonia and finally sulphur. In some more modern works cyanogen is also removed.

The tar is largely taken out in the hydraulic main which is situated on top of the stack of retorts. Here the gas bubbles through a seal of tar and weak ammoniacal liquor. The gas next passes to the exhauster, which is usually of the positive rotary blower type and is the heart of the works, driving the gas forward through all vessels and finally into the holder.

Then the gas passes through various mechanical tar extractors and finally washers or scrubbers, through which water is pumped and where the last traces of tar and ammonia are removed.

Rotary scrubbers are usually employed to remove the cyanogen in the gas in the form of ferrocyanide of potash, sodium or ammonia.

The sulphur is the most difficult impurity to remove. In this country we employ mostly iron oxide mixed with shavings. The H_2S in the gas combines with the iron oxide to form iron sulphide. When all the oxide has been "fouled," or is in the form of iron sulphide, the material is taken out of the purifying boxes and exposed to the air. The oxygen of the air causes the iron sulphide to return to the form of iron oxide, leaving the sulphur in the free state among the material. This can then be used over again, and the process repeated until there is approximately 50 per cent. by weight of free sulphur in the mass, when it becomes too sluggish to act.

In England, lime, or rather the hydrated form of quicklime, CaO, H_2O, is used. This is done because lime removes CS_2 as well as H_2S. The process, however, is too expensive.

After purification the gas is ready for commercial use.

Water gas is treated only for tar and sulphur; coke oven gas for the same products as coal gas.

Producer and blast-furnace gas is treated for tar, ammonia and cyanogen, while oil gas needs only the removal of the tar and sulphur. Therefore, since the coal gas by-products cover those obtained from any other gas, we can sum up the commercially valuable substances produced from gas manufacture as

1. Gas, about 10 000 cu. ft. from ton of coal.
2. Coke, about 1 350 lb. from ton of coal.
3. Tar, about 13 gal. from ton of coal.
4. Ammonia, about 5 lb. pure NH_3 gas from ton of coal.
5. Cyanogen, about 2 lb. ferrocyanide of potash from ton of coal.
6. Sulphur, varies with coal.
7. Retort carbon, varies with heats, etc.

The gas, coke, tar and ammonia are all very valuable and constitute the main source of revenue. It is useless to recount the applications of each except to remind you that modern organic chemistry was begun largely by studying the properties and constitution of coal tar. I will therefore omit a more detailed description and pass on to the

Station Meter.

The gas after passing the purifiers is ready to sell, except that the amount made must be determined in order to keep the several parts of the works under control. This measuring is usually done by means of a large four-compartment drum, which revolves in a cast-iron case filled about two thirds full of water.

The inlet and outlets of the drum compartments are so arranged that when the outlet is *below* water, the inlet is above and the compartment fills with gas. The drum revolves something like a squirrel cage, and shortly after the inlet dips below water the outlet comes above and the compartment discharges its contained gas. The cubical contents of the compartments being accurately known, the motion of the drum is communicated by gearing to the dial, and thus we have an apparatus which accurately measures the gas made. It is customary to make proper corrections for temperature and barometic pressure, and we reduce the gas manufactured to 60 degrees fahr. and 30 in. barometer height.

On account of the large size of station meters various forms of proportional meters have been tried. These measure only a small fraction, usually 1 per cent. of the make, and are arranged to register the total, but so far there is no absolutely reliable proportional meter on the market.

A new form of station meter called the rotary is now on the market and is said to be satisfactory. It is in principle of the anemometer type, and as it is much smaller than the old-style meters it bids fair to find extended use. I question its absolute accuracy, however, very much.

Leaving the station meter the gas passes into the

Gas Holders.

These are the storage reservoirs for gas, and allow us to manufacture uniformly during the 24 hours of the day. The rate of send-out is constantly varying, but the holder takes care of that.

Gas holders are now usually constructed of steel throughout, and can be bought up to 20 000 000 cu. ft. capacity. In St. Louis we have two 4 000 000 ft. holders, and I will give you a few of the principal points of such a construction.

Diameter of tank	210 ft.
Depth of tank	34 ,,
Height of holder	160 ,,
Steel work required	2 200 tons

Cost, about $250 000 complete.

These holders are designed to safely withstand a wind load of 25 lb. per square foot on the full exposed diametrical section at full height, and a snow load of 5 lb. per square foot of the upper area, considered as being entirely massed on one edge of the crown.

For a more complete discussion of these immense structural steel holders I will refer any one interested to an article I wrote for the *Wisconsin Engineer* in 1901. There is now only one more subject I wish to touch upon before leaving the manufacturing end, and that is,

Chemistry and Photometry.

The gas business is essentially the business of a chemist. Where do we find richer fields for investigation or better scope for that research for economy than in this industry? Take ordinary coal gas. It is composed largely of some eight or ten substances, but there are traces of numberless organic changes, decompositions and formations during its evolution in the retort. Ammonia, cyanogen and tar afford unlimited possibilities, to say nothing of the analyses of the crude substances, coals and oils.

Then in a works there are flue gas analyses and numberless thermochemical reactions to be investigated. I have been in this business for years, and have devoted a great deal of study to it, and yet to-day I feel as if I were at the threshold of an unknown world timidly seeking light. For instance, we must find a cheap way to manufacture natural gas artificially, that is CH_4, and yet no one has so far found it.

Photometry is likewise in a rather unsatisfactory state. We read of mean spherical candle-power, of the Harcourt pentane lamp, the Hefner amyl-acetate standard or a standarized electric incandescent unit, and yet these ultimately refer to a sperm candle of certain physical characteristics and burning at a certain rate as the basis of comparison. Let us question a little deeper, and ask what is the real nature of that standard light, and how can we satisfactorily compare it to, say, Peter Cooper Hewitt's mercury vapor lamp? I leave it to you to ask if there is work ahead in this line.

Leaving now the first great division of the gas business, viz., manufacture, I will take up

Distribution.

This subject will be treated in a very short manner. The gas mains mostly used to-day are of cast iron, but clay, wood and

steel pipes have all been tried. An ordinary system consists of large mains even up to 48 in. and 60 in., leaving the works and acting as feeders. The secondary mains may be 6 in., 4 in. or even less, but in large cities the practice is rapidly tending to a minimum size of 6-in. cast pipe. In these cases the gas pressure is only from 1 to 2 or 3 oz. per square inch, and the natural result is that with a rapidly growing business the sizes of pipes soon prove insufficient. The remedy in former times was to build district holders and thus help out the pressure, but nowadays more economy is necessary.

I can best illustrate the case by telling how we are handling this problem in St. Louis. We first ran a 24-in. belt line around the city, passing all the gas works and near all present district holders. This is so arranged that the gas made at the works is pumped into this line at 5-lb. pressure per square inch. During the night after 10 P.M. and at periods in the day time, the district holders are filled by merely opening valves and allowing the 5-lb. pressure to force the gas into them.

Then at meal times and especially in the evening about six o'clock, when the peak load occurs, all holders are full to keep the pressure up in the low-pressure system. At various points in the city, where formerly district holders would have been placed to keep up the pressure in the neighborhood, we now use pressure-reducing governors from the 24-in. 5-lb. belt line. These governors are placed in manholes in the street, and serve the purpose of district holders as far as the pressure is concerned remarkably well, besides being so cheap to install.

For serving the belt line we use positive rotary blowers, in some cases direct connected to gas engines, since such blowers have their limit of reasonable efficiency near 5-lb. pressure. If we had desired to use 10 lb. we should either have been obliged to use two rotary blowers in series or blowing engines. For city use, where electrolysis is so frequently met, we did not feel safe in going over 5 lb. nor did we deem it wise to use anything but cast-iron pipe.

For reaching suburban communities, however, we compress the gas up to anywhere from 20 to 50 lb. pressure per square inch. Large quantities of it can then be transmitted a long distance through comparatively small pipe, and for this work screw pipe is usually employed. The reduction to working pressure is accomplished either by district governors or a governor at each house.

The whole system resembles nothing so much as an electric

alternating current distribution. The high-pressure lines take the place of the high-tension primaries, the governors of the transformers and the low-pressure pipes of the low tension secondaries.

For supplying the individual consumer small service pipes are run, and are generally 1.25 in. to 2 in. steel or wrought screw pipe.

One of the great bugbears of underground piping to-day is the electrolysis action resulting from the return currents of the street railway systems. At places in St. Louis it is very severe. The remedies suggested have been, better rail bonding, connecting the pipes and rails by wires at certain points, insulating pipe joints, covering the pipes with pitch and by other non-conductors, and others, but these are not remedies; they merely postpone the fatal day of trouble.

It may be the real way to accomplish the result permanently is for the street railway system to adopt alternating current traction, and it is to be hoped that those who are working on this problem will succeed in demonstrating the practicability and desirability of this system in respect to electrolytic action.

Consumers' meters are next in order. These little machines, which are so often maligned and said to work while the gas man sleeps, are really very ingenious and accurate instruments. They are usually of the dry type, having a partition in the center, and on each side tin disks vibrate back and forth. These disks are connected to the center plate by leather diaphragms, and the gas passes in and out through little slide valves like those on simple steam engines. The cubical contents between these disks and the meter plates are accurately known, and the vibration back and forth moves the index on the dials by means of gearing. I will now consider a few of the appliances by which gas is consumed.

Appliances.

The Welsbach light has been an important factor in maintaining gas for illuminating purposes in face of the electric light. Its spectrum is as near to sunlight as any electric device yet produced, except, of course, the Nernst lamp, which is practically the same. Gas will probably be used for lighting purposes for a long time to come, but its most rapid advance of late is in the fuel field. Gas stoves, gas water heaters, metal melters, industrial fuel devices, and even house heating, preferably by hot water systems with gas fires in the furnace, together with innumerable other appliances, are all so well known that it is useless to describe them.

A recent and rapidly increasing development in gas engines is very noteworthy. Already the steam engine and steam turbine are left far behind in the race for thermal efficiency, and that with the gas engine hardly started. We can reasonably hope for a thermal efficiency of 50 per cent. before long. Then the possibilities of the gas turbines are hardly dreamt of to-day.

Gas engines of 5 000 h.p. are in use to-day. Their operation is very satisfactory, and their regulation is so close that alternators driven by separate engines are readily kept in step.

In conclusion I will say that I realize that I have probably passed lightly by those portions of the gas business which may be of greatest interest to the general public, and have dwelt on such things as thermochemistry, heat reactions, etc., to a great extent. But I did this with the complete consciousness that I was addressing a body of intelligent engineers, and my object was to at least partially demonstrate the fact that there are many worlds to conquer in the gas business as well as in other lines, even though the progress made so far will compare favorably with other scientific achievements. Our great universities are establishing courses in chemical technology, our great manufacturing establishments are conducting experiments on gas producers and gas engines (may we say gas turbines?) and the engineering fraternity at large is more interested than ever before in gas developments.

I wish to extend a hearty invitation to any member of the Engineers' Club who may wish to inspect our plant or investigate any portion of our business, to visit us, and will welcome a chance to be of service in this line.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by July 15, 1907, for publication in a subsequent number of the JOURNAL.]

PEAT COKE.

By Max Toltz, Member of the Civil Engineers' Society of St. Paul.

[Read before the Society, March 11, 1907.]

In his address delivered at the Minnesota State Fair, St. Paul, Minn., on September 3, 1906, Mr. Jas. J. Hill, president of the Great Northern Railway Company, stated that "according to dependable authority our main available coal supply will not give more than a century of life. The estimated life of the Pennsylvania anthracite coal fields, whose narrow area has permitted closer approximation, is put at little more than fifty years. The larger supply of soft coal has to answer the demand many times as great.

"It is certainly a moderate statement to say that by the middle of the present century, when our population shall have reached the two hundred million mark, our best and most convenient coal will have been so far consumed that the remainder can only be applied to present uses at an enhanced cost, which would probably compel the entire rearrangement of industries and revolutionize the common lot and common life. This is not a mere possibility, but a probability, which our country must face."

This statement comes from a man of international fame and of a knowledge on national economics sufficient to warrant its correctness. It is the province of the engineer to devise means of overcoming this shortage of fuel or, in other words, to provide measures by which the supply of heat material can be prolonged.

What can he do, what must he do, to substitute a material from which heat can be generated? Without heat there is no energy, and without energy there is no life. First of all he should stop the waste of valuable material and learn to economize. It is well known that the heat produced from coal is utilized only to the following extent:

7 per cent. in a good slide valve engine;

8 per cent. in a plain Corliss engine;

9 per cent. in a compound engine;

11 per cent. in a steam turbine; and

12 per cent. in a reheating compound or a triple expansion engine.

Although in European practice during the last ten years these values have been increased to 16 per cent. by the use of highly superheated steam, it is only during the last year that a movement towards this great economic feature has been started in our country. Yet this is only one of the features of fuel economy. What amount of heat and energy is being lost by the escaping gases of iron and steel furnaces and coke ovens which should be and probably will be converted into hundreds of thousands of horse-powers by gas engines? Lignite, the lightest coal and the greatest gas producer, will surely demand the adoption of suitable gas engines for power purposes. On oil and natural gas for heat utilization no great reliance can be placed as the supply is getting smaller all the time. The thousands of immense water powers, still hidden in the virgin wilderness of our great mountains and elsewhere, must be harnessed to do our bidding. The heat of the sun can be stored, as has been proved in isolated cases. We shall have to *utilize* the power of the ocean wave, and even the wind should be called upon to come to our assistance. But the exhaustion of the coal measures will not finish the fuel supply because there is a material which easily and successfully will supplant coal for fuel and of which there is a great abundance in our country. This material is peat, not in its original form, air-dried or compressed, but peat converted into coke. Although enterprises have sprung up to make peat briquettes a substitute for coal, every one has gone under, due to the cost of transportation and the difficulty of getting rid of the 80 per cent. to 90 per cent. of moisture which is contained in the excavated peat. No compression machine has been able to squeeze out more than 25 per cent. of this moisture. The sun and the wind must do the rest. Mechanical means of drying have been tried but found too expensive. Coke made from peat is quite a different proposition, because it concentrates the heat-bearing masses and makes this fuel less bulky. The following description of this new process will present an interesting phase of the future fuel, but before going further into details of the production of peat coke it will be necessary to review the quantities of raw material from which coke could be manufactured.

According to reports of the state geologists, the main peat beds or bogs are located in the middle West, in some Eastern states and in the South. In fifteen states reported, the total area amounts to 7 000 000 acres, with an estimated average depth of 10 ft. A conservative estimate of the total area in the United States will show about 10 000 000 acres of peat beds.

Each acre for 1 ft. of depth of peat will yield 492 tons of air-dried peat containing 20 per cent. of water, and this converted will give 164 tons of the best coke having the same heating value as charcoal, 14 500 B.t.u. The average coal contains about 11 500 B.t.u., the medium between West Virginia coal with 14 000 B.t.u. and Illinois and Iowa coal with 9 000 B.t.u. The value of peat coke is, therefore, 26 per cent. greater, or, in other words, one ton of peat coke equals 1.26 tons of coal. The total output from 10 000 000 acres of peat 10 ft. deep (surely a low estimate, as many of the peat beds have a depth of from 20 to 30 ft.) will be 16 400 000 000 tons of coke which have a value of 20 664 000 000 tons of coal. At the present rate of coal consumption, which is 350 000 000 tons per year, this peat coke would last nearly sixty years. This fuel can be furnished at a great deal cheaper cost than coal, which will be seen later on.

Peat is the partially decayed and compacted remains of mosses and other marsh plants which have become covered with water during the process of decay. Generally the plants grow luxuriantly at the surface but die below and are submerged. The rate of growth is estimated to vary from 1 to 4 in. per year and the depth of beds often exceeds 20 ft., but 10 ft. is more common. The deposits are confined to temperate regions in both northern and southern hemispheres.

At a short distance below the surface the peat is brown and somewhat loose in texture; at greater depths it becomes dense and nearly black, and in many cases it becomes lignite.

In the digging of peat for fuel the bog is partly drained by open ditches and when the excess of water has disappeared the loose surface is removed either by hand or machines.

Owing to its bulkiness peat cannot be shipped profitably to great distances. "The charcoal made from compressed peat is superior to wood charcoal and even compares with coke" (*Americana*).

This latter statement is not correct; it should read "it is superior to coal coke and even compares with wood charcoal." The comparative analysis of peat coke and charcoal is given below.

The peat is excavated with power-driven machines which deliver the material in briquettes 4 in. square and 10 in. to 12 in. long. These are deposited on boards of a size easy to handle and are forwarded either by narrow-gage wagon trucks or by belt conveyors to a place where they are stacked up like brick for air drying. As these briquettes coming from the beds contain

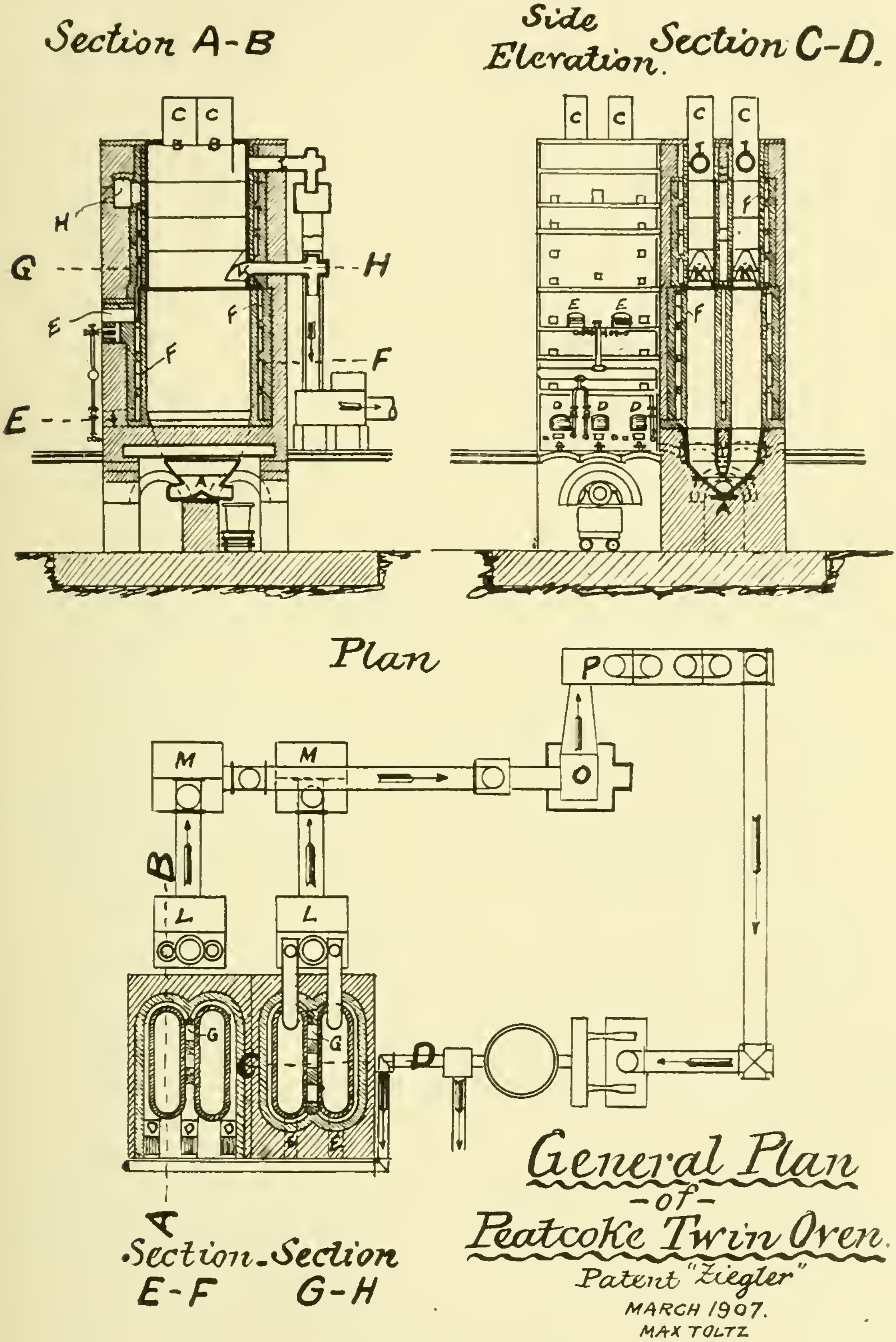
about 80 per cent. to 90 per cent. of water, the air drying will reduce the moisture to about 40 per cent. to 50 per cent. From here they are carried into air-drying chambers where solely by means of the heat given off by the coke-converting ovens the moisture is reduced to 20 per cent. In order to obtain 100 tons of peat containing 20 per cent. of moisture, it is necessary to dry within 24 hr. 200 000 briquettes or 160 tons, half of which is water, which means that 60 tons of water must be evaporated.

The escaping flue gases of the coke ovens having a temperature of about 500 degrees fahr. and being collected by means of a Sturtevant fan are cooled in a mixing chamber to about 160 degrees fahr. This must be done because dry peat can be readily ignited at a temperature of about 260 degrees fahr. About 12 000 cu. ft. of 160 degrees fahr. air per minute are therefore compressed and delivered into the air drying chambers by the fan, which amount is sufficient for the evaporation of 60 tons of water in 24 hr. By means of a slide or butterfly valve the quantity of air passing into the individual chambers is easily regulated. The saturated air at a temperature of about 90 degrees fahr. escapes through chimneys to the atmosphere.

The peat briquettes are fed to these chambers at the top in the same quantities as they are removed from the bottom. These chambers, therefore, are constantly being replenished with briquettes, and their passage is so governed that every particle of peat is subjected to the hot air for at least 24 hr.

From here the dried peat briquettes are moved by conveyors to the top of the coke ovens. These are built in twins, having elliptically shaped retorts of firebrick in the lower half and of cast iron with a thin outside lining of firebrick in the upper half. These again are surrounded by another firebrick shell, leaving an air space which is divided by walls into fire flues. The whole oven is then protected by a common brick wall. The retorts rest upon a cast-iron foundation and end in a hopper " A " (see " General Plan of Peat Coke Twin Oven "), which has two openings for drawing off the peat coke. Each of the retorts is closed on top by cast-iron covers " B " which carry the feed boxes " C." The openings through which the peat is fed and the coke is drawn off are air tight. The dimensions of these ovens are such that in 24 hr. 18 tons of air-dried peat containing from 20 per cent. to 25 per cent. moisture can be converted into coke. The non-condensing gases which are generated in sufficient quantities are used for the firing of the ovens and are fed into the combustion chambers through three lower " D " and

two upper " E " openings, passing thence through the fire flues (" F " and " G ") to the collecting flue " H," which leads to the exhaust fan of the mixing chambers. For every fire flue a peep-



hole on the front and rear side of the ovens is provided for the purpose of watching and taking the temperature, which in the lower flues generally mounts to 1900 to 2000 degrees fahr.,

and in the upper ones to about 1100, 900 and 700 degrees fahr. respectively. The escaping fire gases, as mentioned before, are drawn to the mixing chamber, from which they are led to the drying chambers to be employed for the final drying of the peat briquettes.

The highest temperature in the ovens reaches 1100 degrees fahr. The heat of the products of distillation (water vapor and tar gas) which pass through the pipes "I" and "K," at a temperature of from 360 to 540 degrees fahr., serves to dry by evaporation in the vessels "L" and "M" the ammonium sulphate and acetate of lime solutions from the tar water.

To start the process the ovens must first be fired with peat after they have been filled with the air-dried briquettes. Within 48 hr. sufficient non-condensable gases are given off so that peat firing can be discontinued and the gases ignited. The air necessary for combustion is previously properly heated by the cast-iron hoppers which at the same time serve the purpose of cooling off the peat coke in them.

The regular *modus operandi* is now pursued as follows:

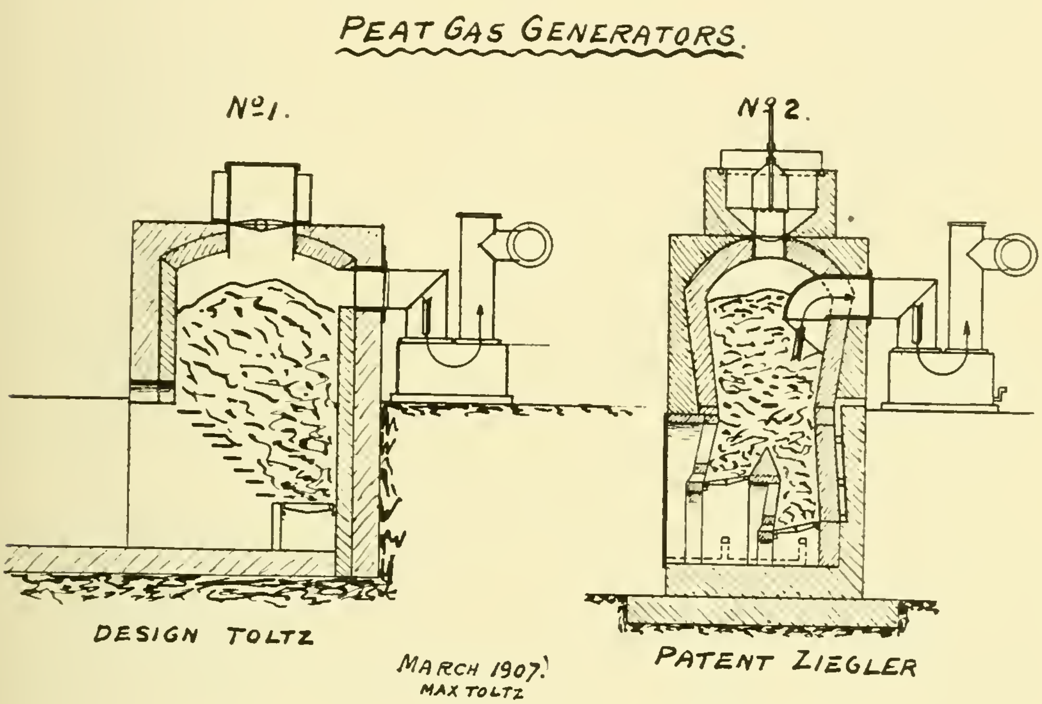
The peat coke is hourly drawn off from the hoppers into air-tight, steel wagons in which the coke must be permitted to thoroughly cool. After each withdrawal of coke fresh supplies of peat briquettes must be fed to the ovens by means of the feed boxes on top. The operation thus becomes a continuous one. In this process of converting peat into coke (dry distillation) the water vapors and tar gas generated are collected by the exhaust fan "O" and driven through the pipe condenser "P," in which by reason of contact with the air, they are condensed to tar and tar water. These two by-products are valuable and are converted into different chemicals which will be described later.

The non-condensable gases are compressed by means of another fan and in this state find employment as fuel for the firing of the ovens and such boilers as may be installed for purposes of this process.

For a consistent operation it is important to obtain the peat as cheaply as possible. The peat machines or excavators should, therefore, be driven by electric motors instead of by individual steam boilers and engines. For the generation of electrical power, gas motors are best employed which are run with peat generator gas. A further advantage is that such a plant is centralized and need not be moved when the location of the peat machines is changed. Peat refuse and such peat as is not suitable for coking answer very well for this purpose in a peat gas generator.

The sketches below show two types of generators.

The first one was designed by the writer and was used years ago in connection with ovens for glass manufacture in the northern part of Germany. The second one was designed by the inventor of this peat coke process. In one hour, from one ton of fairly dried peat, 90 000 cu. ft. of gas of about 140 B.t.u. each are generated. Per horse-power per hour, at the very highest 90 cu. ft. of generator gas are used in a gas motor, so that with this generator a gas motor of 1 000 h.p. is provided with fuel. One thousand cubic feet of generator gas cost, at the most, 3 cents, and 1 h.p. per hour can be obtained for one third of one



cent. By the operation of an electrical power plant, one ton of machine peat will come to $1.18 as per detail cost below. The daily output of 33 tons of peat coke requires 100 tons of air-dried peat briquettes per day, or 36 000 tons per year. On account of climatic conditions in the northern states, atmospheric drying of peat is limited to a period of 100 days; therefore a certain number of peat machines should be worked day and night during this period.

As one machine has a capacity of 30 tons of peat per 10 hr., it will be necessary to run six machines day and night for 100 days to work up a year's supply. One machine should be held in reserve. Each machine is attended by 14 men and one foreman. The cost of air-dried peat briquettes will therefore be:

Daily Wages at Peat Machines.

156 men, per day, $2.00	$312.00
12 foremen, per day, $3.00	36.00
For output of 360 tons, daily wages	$348.00

Expenses for 36 000 Tons Air-Dried Peat Briquettes in 100 Days.

Wages at peat machines	$34 800
5 per cent. repairs on $10 000 (cost of 6 machines)	500
Power to run machine	1 200
15 men transporting and storing briquettes	3 000
15 men turning and stacking briquettes	3 000
Actual cost of 36 000 tons	$42 500

or $1.18 per ton of air-dried peat briquettes, as stated before.

Cost of Plant, Daily Capacity 100 Tons Air-Dried Peat, Yielding 33 Tons Coke No. 1.

3 twin ovens	$60 000
Machinery, etc	24 000
Apparatus for distilling tar water, etc	20 000
6 peat machines	10 000
Total	$114 000

Before final cost of coke can be established the yield of by-products from the tar and tar water must be considered.

The following diagram gives the percentages of chemicals extracted:

Air-Dried Peat Briquettes = 100 Per Cent.

33% Coke No. 1.	4.5% Tar.	46.6% Tar Water.	15.9% Gases.

2% light Oils.	0.7% heavy Oils.	0.3% Paraffine.	1.3% Crude Carbolic Acid.	0.2% Asphalt.

$\underbrace{\qquad\qquad}_{4.5\%}$

0.34% Wood Alcohol.	0.31% Ammoniac Sulphate	0.5% Acetate of Lime.	45.45% Water and Losses.

$\underbrace{\qquad\qquad}_{1.15\%}$ (wood alcohol, ammoniac sulphate, acetate of lime)

$\underbrace{\qquad\qquad}_{46.6\%}$

One hundred tons of air-dried peat briquettes will yield 4.5 tons of tar and 46.6 tons of tar water, which can be manufactured into the following by-products having a value of:

975 lb. ammonium sulphates	per cwt.,	$3.07	$29.93
1 420 lb. acetate of lime	,, ,,	2.35	33.37
72 gal. wood alcohol	per gal.,	.70	50.40
280 gal. light oil	,, ,,	.10	28.00
95 gal. heavy oil	,, ,,	.10	9.50
350 lb. paraffine	per lb.,	.05	17.50
1 580 lb. crude carbolic acid	,, ,,	.03	47.40
175 lb. asphaltum	,, ,,	.01	1.75
Total value of by-products			$217.85

The daily cost of operation of a plant of three twin ovens, having a capacity of 100 tons of air-dried peat briquettes, or 33 tons of coke No. 1, is:

100 tons of air-dried peat briquettes at $1.18	$118.00
38 men. $2.00 per day	76.00
2 foremen, $5.00 per day	10.00
1 chemist	8.00
Interest and depreciation on $114 000, per day (300 days per year)	57.00
	$269.00
General expenses, 7 per cent	18.55
License, per day	7.00
Royalty, per ton coke, 10c	3.30
Total expenses	$297.85
Less value of by-products	217.85
Actual cost of 33 tons of coke No. 1	$80.00

or $2.42 per ton of coke No. 1.

All figures given are conservative and, no doubt, could be reduced from 5 per cent. to 10 per cent. The prices for the by-products are charged intentionally low.

The following are the market values:

Light oil, per gal., 32c.; charged out at	10c.
Heavy oil, per gal., 14c.; charged out at	10c.
Paraffine, per lb., 10c.; charged out at	5c.
Crude carbolic acid, per lb., 11c.; charged out at	3c.
Sulphate of ammonia, per lb., 7½c.; charged out at	3c.

The relative fuel value of the peat coke and the best charcoal is shown by the following analysis:

COMPARATIVE ANALYSIS.

		Peat Coke No. 1.	Charcoal.	Peat Coke No. 2.
Carbon	C	86 to 87.7	87.7	73.89
Hydrogen	H	1.9 to 2.0	3.1	3.59
Nitrogen	N	1.3	0.4	1.49
Oxygen	O	5.2 to 5.5	4.7	0.20
Sulphur	S	0.3	0.3	14.52
Ash	A	3.0 to 3.2	0.9	2.50
Water	H_2O	.0 to 4.3	3.0	3.80
Caloric value (Metric system)	WE	7 800	7 800	6 700
British thermal units,	B.t.u.	14 500	14 500	12 450

So far only peat coke No. 1 has been considered in detail, but a lower grade of coke can be manufactured by this process,

which is called peat coke No. 2. The yield of this latter from 100 tons of air-dried peat briquettes is 45 tons instead of 33 tons, as in the case of coke No. 1.

The Use of the By-Products of Peat.

(1) *Peat Coke No. 1.* — This coke can replace charcoal and can stand the same pressure in a puddle or iron furnace as the best coke made of coal.

(*a*) It can be used in the manufacture of charcoal iron and all such iron as should have a high ultimate strength. Charcoal cannot be bought for less than from seven to eight dollars per ton in the different states at the different charcoal plants. Peat coke can be manufactured at the low cost of about $2.50 per ton, and could be readily sold at from $3.50 to $5.00 per ton. At the present time there are about 180 furnaces working with charcoal in the United States.

(*b*) It is used in the manufacture of zinc, lead and copper, and can be easily introduced because it can replace charcoal.

(*c*) For soldering and welding, this coke develops a highest heat and is most economical.

(*d*) To harden armor plates, this coke in powder form is used in Russia, France and Germany.

(*e*) According to experiments made by Siemans and Halske the best calcium carbide is manufactured from this coke.

(*f*) On account of the quick ignition, this coke in powder form is the best material for firing furnaces in manufacturing cement, pottery, etc.

(2) *Peat Coke No. 2.* — This coke is used for firing locomotives on the Nikolai Railway in Russia. The Russian government is now making tests with this coke for firing the boilers of battleships and torpedo boats. The state railway of Bavaria is also introducing this coke for firing locomotives. It is also used generally for commercial as well as domestic purposes.

(3) *Peat Tar.* — On account of its containing nearly 30 per cent. of creosote this tar can be used directly for impregnating ties and timbers. In Sweden the railroads are dependent upon this product for impregnating purposes.

(*a*) The light oils distilled from this tar can be used either for illuminating purposes or in the manufacture of oil gas, while the heavy oils are used for lubricating purposes.

(*b*) Paraffine, the consumption of which is increasing every year, has a wide field in the manufacture of electrical apparatus, etc.

(*c*) Phenol is carbolic acid in the raw and liquid state.

(*d*) Asphaltum is used for paving compositions, paints, etc.

(4) *Tar Water.*

(*a*) Wood alcohol has the same composition as methyl alcohol, and is used for the same purposes, especially in the manufacture of methyl colors.

(*b*) Sulphate of ammonium is the substitute for manure and is used especially in the manufacture of smokeless powder; also for making ice. The production of the whole world in 1900 was 493 000 tons, 210 000 tons of which were manufactured in England, 120 000 in Germany and the balance in other countries.

(*c*) Acetate of lime in the form of brown or gray lime is used in distilling acid salts and pure vinegar.

The process of converting raw peat into coke, as here described, was invented by the German mining engineer, Martin Ziegler, who is an expert on coke manufactured from low-grade coal. To him belongs the credit for devising means whereby all products of peat are used economically, the main issue being the utilization of the gases for firing. This process can also be used for converting lignite into coke.

The first installation on a larger scale was made in 1894 at Oldenburg, Germany, but many changes in the details have been made since that time to perfect the process. This has been done, and since 1902 several plants have been built in Russia, Sweden and Germany, the most recent and modern being the one at Beuerberg, Bavaria, which has a daily output of 200 tons of coke No. 1. The success which has been accomplished in Europe will tend to hasten the introduction of this process in this country for the purpose of obtaining a first-class fuel at a moderate cost and making useful the vast peat beds of the United States.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 15, 1907, for publication in a subsequent number of the JOURNAL.]

DIFFICULTIES ENCOUNTERED IN EARLY SURVEYS OF THE STATE OF MASSACHUSETTS; HOW THEY WERE OVERCOME AND THE RESULTS OBTAINED.

By Frank W. Hodgdon, President of the Boston Society of Civil Engineers.

[Read before the Society, March 20, 1907.]

In these days when engineers have every aid and opportunity to do their work, it is well to occasionally look back and see how our predecessors had to work, how in many instances they were compelled to construct instruments and tools which can now be purchased at any time. The present facilities for traveling and communication make many tasks easy which in earlier days were quite difficult.

I have recently had occasion to study somewhat the reports and papers of some early surveyers engaged on the Massachusetts State surveys, and thought it would be interesting and instructive to give you some account of the difficulties they encountered, how they overcame them and the results they achieved.

Northern Boundary.

In 1740 King George II decreed that the northern boundary of Massachusetts should be a line 3 miles distant from the north bank of the Merrimac River from the sea to a point 3 miles north of Pawtucket Falls, and thence due west to his Majesty's other possessions.

Governor Belcher of Massachusetts and New Hampshire was ordered to have the line run and marked, and he employed Richard Hazzen to run and mark the straight line west of the point 3 miles north of Pawtucket Falls. This he proceeded to do in the months of March and April, 1741.

The country was largely a wilderness, heavily wooded.

The party, consisting of Mr. Hazzen and six assistants, started Friday, March 20, from his house at Haverhill and reached Colonel Varnum's, near what is now Lowell, about 9 A.M. the next day, having lodged over night at the fireside of Mr. Richard Hall in Tewksbury. At Colonel Varnum's they met George Mitchell, who was to run the line 3 miles north of the river from Pawtucket Falls to the sea. In his company the distance, 3 miles north from Pawtucket Falls, was measured and a pitch

pine-tree marked; this point is now marked by a granite monument known as the Pine-Tree Monument. In the afternoon Hazzen ran the line west 1 mile 16 rods, making an allowance of 10 degrees for the variation of the compass. His party rested on Sunday, lodging with friends, and went to church twice. They started again Monday and ran generally 4 to 6 miles each day, including Sundays, except one, April 5, at Northfield, on the bank of the Connecticut River, where they went to hear Rev. Mr. Doolittle preach both parts of the day.

The following extracts from Mr. Hazzen's diary are a fair sample of the whole:

"Friday, April 10. This day we measured 2:1:20.

"*Remarks*. At the end of half a mile from where we set out this morning we came to Deerfield River, very high and steep mountains being on each side of it, and up and down the river as far as we could see. We met with great difficulty in passing that river, first attempting to wade, and one only got over, and then tried to raft, but it was so shallow in some places we could not use it, and at length we found a place where we all waded over, though with great hazard, the water ran so swift. The mountain on the west side was so steep that we could not carry the chain to measure, but in 4 or 5 hr. time, when we had ascended the top of it, we judged we had got forward on our course 40 poles and no more at the furthest. The snow this day was about 3 ft. deep, the weather fair and the wind northwest. At about sunset we left off measuring and built a fire on the snow and lodged by it.

"Saturday, April 11. This day we began to measure before sunrise and measured 7:0:00.

"*Remarks*. At the end of 4 miles, 3 quarters and 20 poles we came to a small river running north, and where we crossed the river was good intervale land on both sides and a large English camp a little north of the line, and on the east of said river and at the end of 7 miles two large brooks met. One came out of the westward and the other northward and then ran southeasterly.

"We thought both these streams might be branches of Deerfield River and that the camp was made by Captain Wells and company. The land all this day's course was good and fit for settlements, the snow about 3 ft. deep and where we lodged about 5; we lodged where the two brooks met and there we left our bottle, therefore called it Bottle Brook. It snowed a little the greatest part of the day and the wind was northeasterly.

"Sunday, April 12. This day we measured 4:1:50.

"*Remarks*. At the end of 3 miles we came upon the top of an exceeding high mountain, from whence we discovered a large mountain which lies southwesterly of Albany, as also a row of large mountains on each side of us bearing north and south nearest, and a ridge of exceeding high mountains 3 or 4

miles before us bearing the same course, and a fine valley betwixt them and us on each side of the line big enough for townships. At 130 poles further we crossed a branch of Hosek River running southerly, thence to main river Hosek running northwesterly. With difficulty we waded it and lodged by it on the westerly side that night. The first part of the day was good traveling, but heavy by noon, and betwixt the two rivers the snow was almost gone. It clouded over before night and rained sometime before day, which caused us to stretch our blankets and lie under them on the bare ground, which was the first bare ground we laid on after we left Northfield. There was but little wind this day.

" Monday, April 13. This day we measured from Hosek River 4:2:0, which was only over one mountain.

"*Observations.* This mountain was exceeding good land, bearing beech, black birch and hemlock, some bass wood. Over this mountain we concluded the line would run betwixt these and New York government whenever it should be settled, and therefore name it Mt. Belcher, that it might be as standing a boundary as Endicutt's tree. We lodged again on a bare spot of ground by a brook running southwesterly, which being full of clay we named it Clay Brook. We had some thunder showers in the night which obliged us to rise and stretch our blankets. The weather was cloudy all day and no wind stirring and the snow for the last 3 miles about 2 ft. deep — the first mile and a half but little.

* * * * * * * * * ° *

" Thursday, April 16. We measured to Hudsons River 5:0.

"*Observations.* On a small mountain at 4 miles and 40 poles from where we began to measure this morning we had a fair view of the city of Albany bearing from us southwesterly and distant about 8 miles as we judged, and at the same time had as fair a view of the fall of the Mohawk River, called Cohoes or Great Falls above Albany, to our very great joy, and therefore named the hill Mount Joy, the said falls being distant from us 3 or 4 miles; from thence we kept our course to Hudsons River at about 80 poles from the place where the Mohawk River comes into Hudsons River. We went thence to Albany and tarried there that night. The trees standing in our line or near it are well marked, but could raise but few other monuments, the snow in most places having covered the stones. The rivers and streams and ponds are laid down in their proper places exactly where we crossed them, but out of sight altogether by guess. The mountains are laid down as much in form as I could, and many pretty exactly, but they being of such a vast extent it must not be concluded that they are all so perfectly done nor that they are all put down that came within sight.

" Friday, April 17. At 9 o'clock we left Albany and the same night came to Kinderhook, and that night lodged by Derrock Slake's fire.

* * * * * * * * * * *

"Friday, April 24. It rained hard most of the day, yet we traveled from Harvard to Groton, where William Richardson, one of the company, left us and went to Townsend, where he belonged, the rest of us to Dunstable, where we lodged that night.

"Saturday, April 25. I purchased a canoe at Dunstable and came down the Merrimack River to Dracut. We carried our canoe over Pentucket Falls. Zechariah Hildreth, another of our company, stopt at Dracut, where he belonged. We came down the river thence to Methuen, where Mr. Caleb Swan, another of the company who belonged there, left us. The rest of us came to Haverhill about 8 or 9 o'clock, after a journey of 37 days, all in perfect health through God's goodness to us.

"Richard Hazzen.

"N.B. — The weather proved so favorable that we never stopped in the woods for any foul weather, nor did we make a camp any one night and stretched our blankets but three times all the journey, but lodged without any covering save the heavens and our blankets."

The distance was one hundred and ten miles each way and was done in 37 days.

In 1825 the line east of the Connecticut River was resurveyed by Caleb Butler and Benj. F. Varnum, representing Massachusetts Commissioners, and Eliphalet Hunt, representing New Hampshire Commissioners. They found the line marked by Hazzen, and in 1827 Mr. Varnum set granite monuments to mark the line. Between 1886 and 1900 the whole line was resurveyed and re-marked by commissioners from Massachusetts, New Hampshire and Vermont, Mr. Nelson Spofford being the surveyor for Massachusetts. Mr. Spofford's paper, "The Northern Boundary of Massachusetts," read before this Society December 21, 1904, and printed in the Journal of the Association, Vol. 37, p. 1, for July, 1906, discussed the resurveys, besides giving an account of the original running of the line, similar to the foregoing narrative.

Subsequently to Mr. Spofford's resurvey the location of the various monuments is being determined in connection with the survey of the town boundaries, and this furnishes an opportunity to learn how well the original work was done.

Assuming that the line was intended to be straight from Boundary Pine to the northwest corner of Massachusetts, we find so far as the town boundary survey has progressed that none of the points are more than 1 530 ft. off the straight line.

This line was run by an ordinary surveyor's compass and the measuring done with the ordinary old-fashioned surveyors'

chain. The straight line from Boundary Pine to the northwest corner of Massachusetts is almost exactly 100 miles in length.

The line as run deviates from this straight line to the south, the greatest deviation being about 1 530 ft. at a point about 33 miles from Boundary Pine. In general the line deflected steadily to the south for the first 20 miles, reaching a point about 1 200 ft. from the line; then the general course for the next 33 miles was practically parallel to the straight line and from 1 200 to 1 500 ft. from it. In the last 45 miles the line gradually approaches the straight line, coinciding with it at the northwest corner.

Massachusetts–New York Line.

In 1785, at the request of both Massachusetts and New York, Congress appointed Thomas Hutchins, a military engineer who had served in the Revolution as geographer-general under General Greene; Rev. John Ewing, vice-president of the American Philosophical Society; and David Rittenhouse, a distinguished clock and instrument maker, a commission to run out and mark the line between the two states, and it was agreed that the boundary should be a straight line north 15 degrees, 12 min., 9 sec. east [true bearing]. This line was run along the summits of the Berkshire Hills and is about 50 miles long; it was marked by cuts in the ledges and stakes with stones piled around them where there was no exposed ledge.

The instrument work was done principally by Mr. Rittenhouse and Simon DeWitt.

When this line was resurveyed in 1897–98, most of the principal marks were found and they were all practically on a straight line,the bearing of which was north 15 degrees, 12 min., 22 sec. east, varying only 13 sec. from what it was originally intended to be. This straight line in all but one case ran through some portion of the stone piles which were built around the original stakes which had rotted away.

Along the line at various points and at the northwesterly corner of the state were found bounds which were said to mark the state line, but were 50 to 70 ft. from it. It was known that none of these were placed by the commissioners of 1785, though it was stated that some were set to replace marks which were thought to have been placed by those commissioners, but there was no definite information thereof.

This line was run with a transit from summit to summit, the instrument being reversed and the line projected ahead in

the usual way. The points set in this way are those referred to as being practically on line. Between these transit points, down through the valleys, the line was run by a compass, and at these points more deviation from the straight line was found. The measuring was undoubtedly done by the ordinary surveyor's chain.

BORDEN SURVEY OF MASSACHUSETTS.

In the House of Representatives of Massachusetts, in the summer session of 1829, an order was passed appointing a committee " to consider the expediency of determining such a map or maps of this commonwealth as the public exigency requires, and report thereon to the next session of the legislature."

This committee reported at the succeeding winter session, and as a result of that report the following resolves were passed: On March 1, 1830, a resolve directing the cities, towns and districts of the commonwealth to each make a plan of its territory on a scale of 100 rods to an inch and file them with the Secretary of State before June 1, 1830. On March 30, a resolve directing the governor to appoint a surveyor to make a survey and skeleton map of the state, including the external boundaries and most prominent bays within the territory, the intention being to use this survey as an outline and ground plan on which should be plotted the information furnished by the plans made by the various towns. These town plans were made by local surveyors and filed as directed.

Under these resolves Mr. Robert Treat Paine, of Boston, was appointed chief engineer, May 13, 1830, and Mr. James Stevens, of Newport, R. I., on the 25th of June following, assistant engineer, to execute the authorized surveys and to project the map.

From time to time resolves were passed providing for agricultural, geological, mineralogical, botanical and zoölogical surveys, and these were made while the surveys for the map were in progress.

Mr. Paine undertook the necessary astronomical work to determine the latitude and longitude of a number of points throughout the state, and Mr. Stevens undertook the triangulation work to determine the relative position of enough points throughout the state, including those whose latitude and longitude were to be determined by Mr. Paine and such points as were necessary along the state boundary line, to furnish data to make an outline map of the state, on which should be plotted the topography shown on the various plans filed by the towns.

On May 31, 1831, Mr. Stevens made his first report, describing the work of similar character which had been done abroad and stating that there were only two cases of a similar class of work which had been done in the United States previous to the Massachusetts survey: "The first was the survey of the coast of the United States by Prof. F. R. Hassler, which was discontinued immediately after its commencement. The other was that of the state of Rhode Island, which had been but recently completed, and of which there has not as yet been any description given."

He then describes the method of carrying out the work, — first measuring a base line and extending the work by triangulation, describing the spherical work and the necessity for determining the latitude and longitude of various points of the survey by astronomical observations.

He then states that he had explored the location for a base line and found a suitable one on the plains along the west bank of the Connecticut River, at or north of Northampton; he had also explored the country to the west and to a certain extent to the eastward of the proposed base line.

In a later report, transmitted to the legislature on January 31, 1832, Colonel Stevens describes the base line apparatus, built for the survey by the Pocasset Manufacturing Company of Fall River, in the town of Troy, Mass., under the direction of the scientific and practical mechanic, Simeon Borden, Esq., the conductor of that establishment, and at the time a member of the legislature. The whole apparatus was designed by Mr. Borden in accordance with a rough drawing and about an hour's conversation with Colonel Stevens. The microscopes were constructed by Dr. Joseph Rice under Mr. Borden's direction. The other instruments for the survey were loaned to the state by the general government, but were without stands, side plates, etc., necessary for their use. These necessary parts were designed and constructed by Mr. Borden. The cost of the above, together with the necessary drafting tools, was less than $800.

After experimenting with young men who had volunteered for the work, Colonel Stevens finally induced Mr. Borden to leave the machine shop and undertake the measurement of the base line, and he continued with the work until the completion of the map.

Two measurements were made of the base, which was 7.3882 miles [39 009.73 feet] long, the difference of the two measurements being 0.237 in. The second measurement was

completed on the 12th of October, 1831. Then the work of extending the base line by triangulation was commenced. On March 8, 1833, Colonel Stevens describes the work of extending the triangulation, giving details of the territory covered and explored. The triangulation points, wherever practicable, were marked by copper bolts set in the ledges on the summits of the hills. The church spires in the various villages were also determined and many points along the state boundaries. During the winter and stormy weather the calculations of the survey were made. In December, 1833, Colonel Stevens made a report as to the progress of the triangulation work during the year.

The legislature of 1834 began to look for results from this survey. No maps had been made and the notebooks were incomprehensible to the members. The Committee on Education, to whom the examination of these notebooks had been referred, reported that "it appears that the survey has been prosecuted with all the despatch practicable with the perfect accuracy required in the various operations. . . . So great has been the diligence of the engineers, as the journal shows, that even Sunday has not been regarded as a day of rest — a circumstance which the committee observe with regret and which they trust will not continue. . . . The progress of this great work is necessarily slow, but we are encouraged with the possibility of its completion in another year."

The committee recommended that an appropriation be made for carrying on the work, but the matter was then referred to a sub-committee, whose report criticised the engineer for the manner in which the survey had been conducted, but indorsed the recommendation of the Committee on Education that a further appropriation be made because the engineer who, in the opinion of the committee was the only man who could advantageously utilize the work already done, had threatened to resign unless the appropriation was made.

The criticisms of the legislature were so distasteful to Colonel Stevens that, notwithstanding the fact that the legislature made the appropriation which he asked for continuing the work, he resigned his position, and on April 7, 1834, Mr. Simeon Borden, who had built the base line apparatus and constructed improvements to the other instruments, and who had also been employed as the assistant of Colonel Stevens, was appointed by the governor to continue the work.

In Senate Document No. 3 of 1835 is printed a report by Mr. Borden, describing the progress of the work from the begin-

ning up to January, 1835, from which it appears that the triangulation work was still incomplete, and he made an estimate of $4 175 for continuing the work another year. The work continued through 1835 and 1836.

In 1836 Mr. Borden reported that his salary was $1 500 per year, with subsistence; his two assistants received between them $710, with their subsistence. He stated that he had personally observed all the angles of the survey, having had one recorder and one general helper. He described the difficulties he had experienced with fog and refraction in connection with the work on Cape Cod and the Vineyard, and also near the New York boundary.

In April, 1838, the final report of Mr. Paine on the astronomical observations and calculations for determining the geographical positions of 27 points was received. The field work of the triangulation of Mr. Borden had been completed, but the calculations and measurement of the verification base in the southeastern part of the state had not been finished, neither had the plotting of the map been commenced.

On February 18, 1839, a special committee of the Senate, consisting of Jeremiah Spofford, S. G. Goodrich and Jared Whitman, was appointed to inquire when a map of the state was likely to be completed, and to consider the expediency of a further expenditure for that purpose. This committee reported on April 4 that in their opinion "the state had been, in some instances, subjected to gross imposition and that expenditures have been incurred which tended little to the furtherance of the object in view." The committee did not feel that they had the data on which to found an opinion as to the competency of the several agents. They further reported that "some of the agents, finding themselves comfortably reposing upon the liberality and confidence of the state government and people, have been in no haste to bring their labors and their emoluments to a conclusion."

The committee, notwithstanding, reported, as had all previous ones, that it did not feel justified in recommending a change in the method previously adopted for completing the map.

On February 14, 1840, Mr. Borden, being then engaged in plotting the third section of the map, made a detailed report to the governor, describing the methods of executing the work and the difficulties which he had encountered.

The map was plotted on a polyconic projection, and was

divided into five sections, the first section being practically the area west of the Connecticut River, the second section extended about half way from the Connecticut River to the sea, the third and fourth sections consisting of the area between the second section and the sea, the northerly half constituting the third section and the southerly half the fourth section and the fifth section included the remainder of the state, mainly Cape Cod. In each section a central meridian line was determined and rectangular coördinates determined for all points in each section in relation to this meridian line. In addition the latitude and longitude in relation to the equator and meridian of Greenwich were determined for all the main stations.

After plotting the outline of the state and the various triangulation points, an attempt was made to complete the map by reducing the plans furnished by the various towns to the scale of the state map and then inserting them in their proper positions on the state map, using the positions of the triangulation stations, including churches and similar objects, as common points, they being shown both on the state map and on the town plans. It was found that the town maps were so inaccurate that it was impossible to complete the state map with any degree of accuracy in this manner.

In 1838 a legislative act provided that those towns which had returned inaccurate plans should have new ones made and filed in the manner provided for the original maps; but with no other data than that furnished by the plans themselves it was impossible to determine which were the accurate and which the inaccurate plans. In order to determine this, if possible, the governor authorized Mr. Borden to ascertain which were the accurate towns by measuring lines across them and comparing these distances with the corresponding distances scaled on the town maps, these measurements to be so made as to be useful in plotting the topography of the town. An attempt was made to do this with the result that nearly all the plans of towns in the western part of the state were found to be more or less erroneous. In one case, when they had nearly completed the examination of the town, they learned that no survey whatever had been made for the purpose of making the map of the town, not even an angle or a line had been measured. The selectmen had obtained from some source the bearings and length of the outlines of the town, which they furnished to the person who made the map. This person drew the outlines or boundaries of the town in accordance with the data furnished him, and the

roads, streams, etc., he merely drew upon the map with no other guide than his judgment. The measurements in this town made by Mr. Borden furnished sufficient data to correct the plan, there being but few roads in the town, most of which were measured. The plan furnished by this town was a full mile too short.

While making these examinations numerous secondary points were determined which furnished much additional information to assist in correcting and adjusting the various town plans.

The method of making several town maps, as described by the surveyors who made them, was as follows: The selectmen agreed with the surveyor to survey the town by the day, and furnished the surveyor with the bearings and lengths of the boundary lines taken from the ancient surveys. With these outlines and a survey of a few of the principal roads, he made the map, cutting off or lengthening the roads wherever necessary to keep them within the outlines as laid down from the data furnished by the ancient surveys. The unsurveyed roads were sometimes drawn by eye whereby the map of the road was made to somewhat resemble the original in its various turnings and windings. Sometimes they were merely directed by the edge of a ruler and had no resemblance to the road they were intended to represent.

Many towns contracted to have a map made for a certain sum and agreed to furnish the surveyor with the outlines and allowed the privilege of sketching many of the roads. In contrast, many towns had faithful surveys made of their whole territory and furnished very good maps, except that topographical representations were generally omitted or executed in a very imperfect manner. A few maps showed the topography very well.

The topography as finally placed on the map is due largely to sketching done in the field by Mr. Borden and his assistants.

Various methods were used for fudging the town plans to make them fit together. Plans of railroad surveys, which had then been made, were placed at Mr. Borden's disposal, and were of material assistance in helping him to adjust these town plans. With the assistance of Mr. Alvan Clark an arrangement which he calls the " Camera Lucida " was used for reducing the various maps to make them conform to the sizes required. In some cases the maps were cut into small sections and these sections either overlapped or spread apart so as to bring the total area

to correspond with the space on the state map, determined from information furnished by plans of adjoining towns or by special surveys. Some of the towns which were resurveyed by the local authorities were still so crude that they could not be satisfactorily adjusted into the state map, and had to be again resurveyed by Mr. Borden.

The map was finally completed in 1841, and a contract was made for having it engraved on copper on a scale of 2.5 miles to the inch and finished in 1842, but the engraving was delayed and the six plates, making a map 7 by 4.5 ft., were not finally finished until 1844, when a contract was made with Charles Hinckley, of Boston, to print the map and place it on sale at $5 each and pay the commonwealth $1.50 royalty for each map sold. The commonwealth itself ordered 760 copies at $3.50 each, the price to the public less the royalty.

I have not been able to learn the exact cost of the work. In 1841 the cost is given as follows:

Agricultural survey	$8 473.53
Astronomical survey	8 893.75
Trigonometrical survey	48 596.71
Geological survey, first and second editions	7 631.67
Geological and mineralogical re-examination	6 869.76
Botanical and zoölogical	4,113.45
	$84,578.87

At the same time the following estimate was made of the cost of completion:

Geological survey	$2,500.00
Botanical, etc	1 800.00
Trigonometrical, field work and plotting	2 000.00
Unpaid bills	1 760.00
	$8 060.00

The engraving was afterwards contracted for at $3 800.

Assuming that the above estimates were correct, the total cost was $96 438.67, of which $65 050.46 was for the survey and map, to which should be added the cost of the town plans, which was paid by the towns.

This was one of the first pieces of geodetic work done in the United States. The Coast Survey had previously established the latitude and longitude of certain points, which determinations they continued to use up to 1880, after which they used the results of their later observations.

Comparing the location of Prospect Hill, Waltham, as de-

termined first by the Coast Survey and later by Messrs. Paine and Borden, with the revised position adopted by the Coast Survey as the result of its observations up to 1880, we find that the position determined by the surveys of Mr. Paine and Mr. Borden to be very much nearer the revised determination of the Coast Survey than the position originally determined by the Coast Survey, as shown by the following tables:

PROSPECT HILL, WALTHAM.

	Latitude.	Longitude.
Borden, original	42° 23′ 19.25″	71° 15′ 33.76″
Borden, revised	42° 23′ 17.91″	
Coast Survey before 1880	42° 23′ 16.842″	71° 14′ 54.393″
Coast Survey after 1880	42° 23′ 18.831″	71° 15′ 15.333″

Longitude.

Borden, 18.427″ more than latest Coast Survey.
Early Coast Survey, 20.940″ less than latest Coast Survey.

Latitude.

Borden, original, 0.419″ more that latest Coast Survey.
Borden, revised, 0.921″ less than latest Coast Survey.
Early Coast Survey, 1.989″ less than latest Coast Survey.

Various comparisons made throughout the state have shown that the principal triangulation points of the Borden survey are determined probably within 5 to 10 ft. of the position obtained by the latest observations.

The results of the triangulation work as published by Hon. John G. Palfrey, the Secretary of State in 1846, are known as "Palfrey's Tables"; they are prefaced by an introduction and explanation prepared by Mr. Borden and by Mr. Charles O. Boutelle, who was one of Mr. Borden's assistants and afterwards a well-known assistant of the United States Coast and Geodetic Survey, describing the methods of using the information and the necessary tables and formulæ to enable a surveyor to use it without recourse to other books except logarithm tables.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 15, 1907, for publication in a subsequent number of the JOURNAL.]

DISCUSSION ON MR. MANSON'S PAPER, "THE STRUGGLE FOR WATER IN THE GREAT CITIES OF THE UNITED STATES"

(VOL. 38, PAGE 103, MARCH, 1907).

MR. DESMOND FITZGERALD. — The part of Mr. Manson's paper in which the writer is particularly interested is that relating to the water supply of the city of San Francisco. Having been employed by that city for a period covering about two years to aid in the study of many of the questions connected with that supply, and having given testimony upon the value of the works of the Spring Valley Water Works, the writer had an excellent opportunity to become familiar with the troubles menacing the city and to admire the high-minded ideas and the plucky fighting qualities displayed by Mr. Manson in defending the best interests of his city. In San Francisco more than in any other community with which the writer is acquainted, the political boss and the corrupt official are both in evidence. What that city needs more than anything else is a few honest men in its government.

In the Sierras, nature has provided an ideal source of water supply, but what with the dog-in-the-manger policy of the government and the active work of private companies and promoters there seems to be a poor chance for the citizens to secure what they really need for their own health and happiness.

In 1903 the writer spent three weeks traveling over the water-shed of the Tuolumne River in company with Mr. C. E. Grunsky, at that time the city engineer of San Francisco; the nature of the water shed and the opportunities for storage were carefully observed. It would be difficult to find a more perfect catchment area. It is composed largely of bare granite which has been scraped smooth by glacial action. Its area is sufficient, and in one of its valleys, the Hetch Hetchy, there is a site for a storage reservoir of enormous capacity which can be developed at comparatively small expense. The great difficulty is the distance from the city, about 150 miles, but when all the advantages and disadvantages are carefully weighed it seems probable that the wisest course for the city to pursue will be to move in that direction and to turn a deaf ear to the many schemes put forward in the interest of promoters. If all the towns and cities within a reasonable distance of San Francisco would unite in forming a Metropolitan District the burden could be more

easily carried. No one who has not studied the variety and complexity of the money interests involved in the water question in San Francisco can really form an idea of the difficulties to be overcome. The people at large seem to have been content to leave the solution of their most important problems to those who are concerned principally in filling their own pockets from the public crib. It is to such men as Mr. Manson that the city is largely indebted for an intelligent appreciation of the real issues in the struggle, and he has happily the courage of a real reformer.

DISCUSSION ON MR. RICHARDS' PAPER, "FIRE PREVENTION APPARATUS" (Vol. 38, Page 196, April, 1907).

Mr. R. B. Green. — It is evident that no one system of fire protection can be depended upon to guard against such a general catastrophe as that which led to the San Francisco fire. In the search for all possible emergency aids it would seem that possibly deep trunk sewers might furnish a supply of water for a fire engine's suction when all regular water supplies are crippled. Every manhole would be a possible suction well.

A shock that would cripple a water main under pressure might break a trunk sewer, but would probably not choke it to prevent both ground water from coming down and back-water from backing up from the outlet, unless there should be a tidal wave, such as would cripple even a fire-boat service. Back water often extends in trunk sewers up through the low level business sections of water-front cities, and could be had in new ones by dropping a small portion of the invert below outlet level. A brick intake main extending back through the lower parts of a town would be similar, but more costly. Similarly, sewers in higher districts known to have large inflows of ground water might also furnish a certain amount of aid in extreme emergencies. Bags of sand to dam a small flow or drop-sumps would aid in the smaller sewers.

Gates or temporary dams at the outlet of large sewers would aid in backing their flow up to the higher levels distant from the harbor front. This effect would be aided by having the fire boats pump into the sewers after their outlets were closed.

OBITUARY.

Nelson Spofford.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

NELSON SPOFFORD, son of Sewall and Elizabeth Nelson Spofford, of Georgetown, was born in 1826. In the earlier part of his business life he taught school for several years, an experience which doubtless had its effect in the development of his characteristic qualities. He established himself in Haverhill, succeeded his brother-in-law, Captain Nathaniel M. Edwards, in his civil engineering office in 1861, and came into possession of the business and maps of Henry D. Thoreau, the celebrated author, who some years before practiced surveying in Haverhill. The pursuit of that business became his principal life work. He made plans of a large part of the city and became one of the best known of its citizens. Many of the streets of Haverhill were located by Mr. Spofford's advice, and he proposed a street parallel to Merrimac Street and two hundred feet north of it. He continued his activity to the end of his life. Within the last two years he made a preliminary survey for a street railway from Haverhill to Danvers and Salem.

Mr. Spofford's work in the city of Haverhill led to his noticing the imperfection of the marking of its boundary on the New Hampshire line, and he promoted the passage, in 1885, of Acts of the legislatures of Massachusetts and New Hampshire for the re-marking of the line and the setting of monuments. He was appointed one of the commissioners for this work on the part of Massachusetts, but shortly afterward resigned to become their surveyor, and he devoted the greater part of his time for the rest of his life to this work and its continuation along the Vermont boundary of the commonwealth. His thoroughness was such that he had researches made in England to obtain documents, and he exercised his skill in some novel ways in running the lines. He presented some account of the work to the Boston Society of Civil Engineers in December, 1904. He made a gift to the library of the Society of a copy of the valuable report published in 1846 by the commonwealth upon the Borden Survey, containing the tabulated geodetic positions of the points determined.

He was a skillful workman in wood and iron and delighted in ingenious contrivances in his workshop. He was the inventor of the Spofford bit brace for carpenters, which has become known and sold throughout the country, and for several years he received a considerable sum in royalties from that invention. He also invented an equal arc meter for use of engineers. To establish his views on some practical engineering or scientific subject, local history, county, state or national affairs, he was willing to spend money and much time, even to neglecting his business. He was a reader of practical and scientific works. His interest in public affairs continued as long as he lived. He published during the last few years of his life communications to the newspapers upon the boundary question and upon other subjects, as the Panama Canal, fireproof construction and the metric system of weights and measures, to whose adoption he was violently opposed.

He was of domestic tastes, was industrious, abstemious in his habits and was energetic and persevering to an exemplary degree.

He married Lucy A. Edwards, of Haverhill, and two sons, John S. Spofford and Nathaniel Spofford, survive him. He died at Haverhill, October 3, 1906, after an illness of only a few days.

Fred. Brooks,
Richard A. Hale,
Committee.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVIII. JUNE, 1907. No. 6.

THE DIVERSION OF THE COLORADO RIVER INTO THE SALTON SINK AND THE EFFORTS MADE TO RESTORE IT TO ITS FORMER CHANNEL.

BY J. A. OCKERSON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, February 20, 1907.]

NONE of the physical features of our country has attracted such widespread attention during the past year as the Salton Sea and the Colorado River. Frequent articles have appeared in magazines and newspapers describing more or less accurately the existing conditions, the cause of the Colorado break, and the effect thereof. Many of them are grossly exaggerated as to the ultimate size of the so-called sea and its possible effect on the climate.

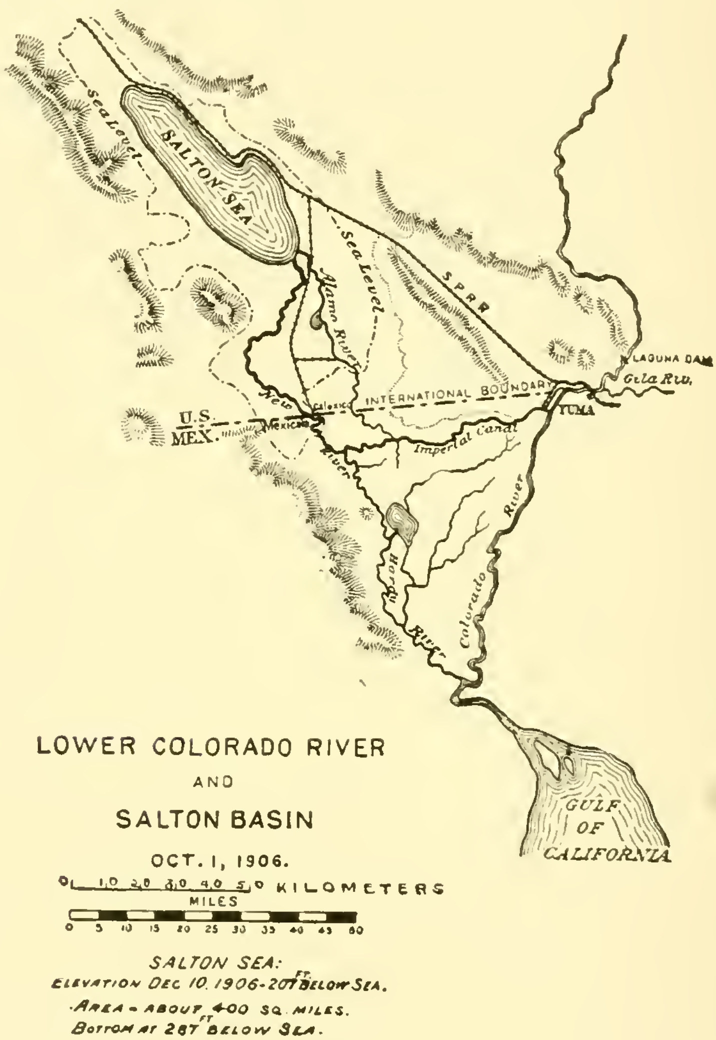
The writer visited the break in August, 1906, just before the active work of closure was begun by the Southern Pacific Railway Company, and again in December of the same year, shortly after the work had failed.

The Gulf of California many centuries ago extended in a northwesterly direction some 150 miles from its present northern terminus. The mouth of the Colorado River was then about 120 miles from the extreme northerly end of the Gulf, and its sediment-laden waters formed a delta which finally extended across the salt water and cut off a portion thereof, which later became the Salton Sink, now more generally called the Imperial Valley.

The river reached the gulf with a slope of over 2 ft. to the mile and readily built up a barrier clear across to the foot hills of the Cocopah range of mountains, and then followed the eastern slope as its main outlet. This delta ranges in height

from 130 ft. above sea level at the United States — Mexican boundary line to something over 20 ft. above sea level on the western side of the gulf basin. The normal slope to the gulf is now about 1.7 ft. per mile in a distance of about 75 miles. A mesa extending from the hills at Yuma downstream limits the flow to the eastward.

The waters of the northern portion of the gulf, which were cut off by the delta deposits, evaporated in the course of time



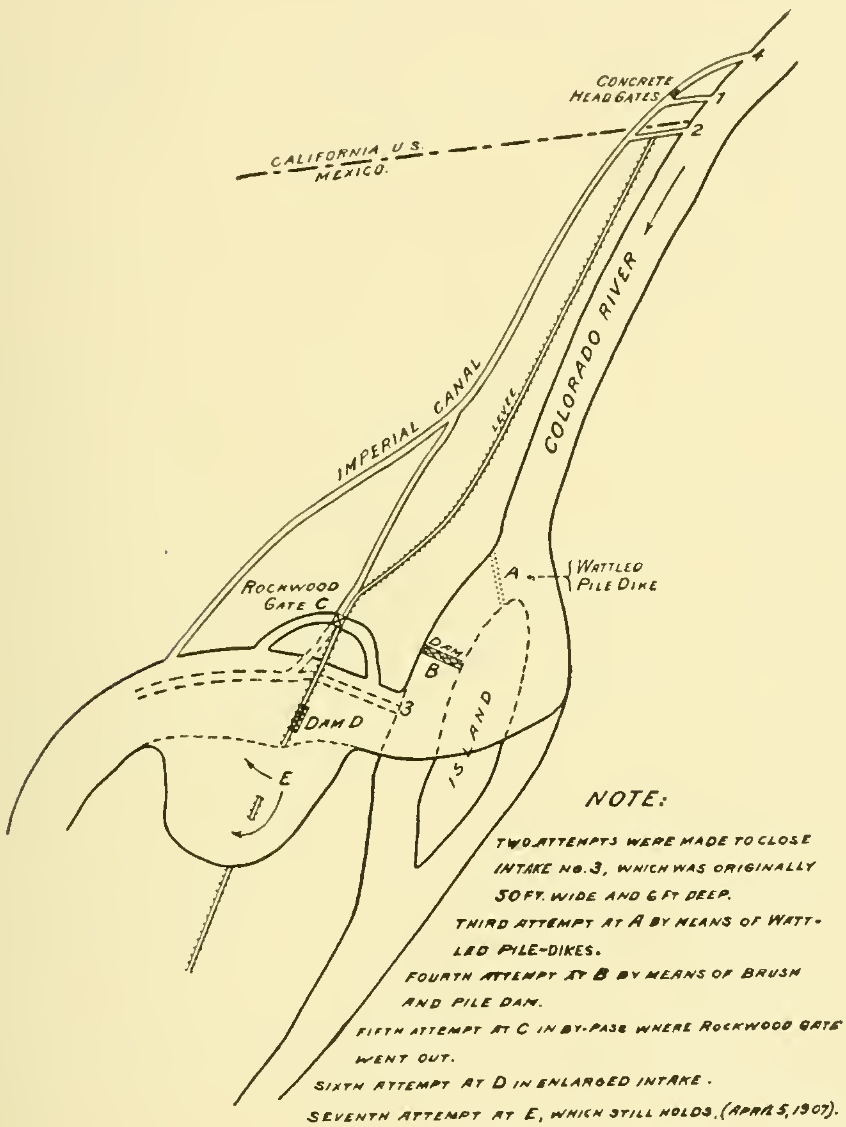
and the basin became dry, leaving extensive deposits of salt. The bottom of this basin is 287 ft. below sea level.

The Southern Pacific Railway, after crossing the Colorado River at Yuma, reached the edge of the sink some 60 miles to the westward, and there its comparatively smooth surface was so attractive that the road follows it for a distance of about 75 miles.

Without water, this vast plain, with an area of about 4 000 sq. miles, was a torrid desert, divided between the United States and Mexico.

The alluvial deposits of the Colorado are of great depth and undoubted fertility when supplied with sufficient water to nourish growing crops. It was natural, therefore, that some means of irrigation should be sought, and the Colorado River was the natural source of supply.

The boundary line between the United States and Mexico is so situated that water taken from the river north of the line



must be carried southward into Mexico around the base of a sandy mesa and then across the line again to the California lands north of the boundary line.

As early as 1893 a company was formed, known as the Colorado River Irrigation Company, to irrigate what was then known as the Colorado desert and now known as the Imperial Valley in southern California. Their work proved a failure, and they were succeeded by the California Development Company, which is responsible for the present trouble.

This company began work by tapping the river on the right bank just above the boundary line, and carried the water through a canal, following the route heretofore indicated.

In order to establish their rights in Mexico and secure certain privileges therefrom, an auxiliary company was organized with a Mexican charter, having essentially the same directorate as the American company.

By 1903 the Imperial Valley had acquired such a population that the supply of water was not sufficient, and the canals were so badly located as to slope that they silted up very rapidly, the machinery owned by the company being inadequate to keep them open. They then opened a second intake just below the boundary line and leading directly back to the canal. This still proved to be inadequate, and they obtained a concession to take 10 000 cu. ft. of water per second from the river in Mexico. At the beginning of the hot season of 1904 the lack of water became so serious in the valley that it was decided to cut a third intake at a point 4 miles below the boundary line. This intake, No. 3, was located behind an island which divided the river into two channels. The cut was about 50 ft. wide and about 6 ft. deep, and led directly back to the canal. It was completed in October, 1904. No head gates or controlling works were provided, owing, it is now said, to lack of funds. Even this intake silted up at low water and had to be dredged out, but the floods in the fall of 1904 started active erosion, and by the middle of December the water found its way to Salton Sink, via the New River, and thus began the present Salton Sea.

By the spring of 1905 the width had increased to 100 ft. and the depth to 20 ft., and it was deemed best to close it. The plan adopted was to drive piling across the channel near the river and fill in between the rows of piles with willows and bags of sand used as ballast. No effort was made to secure the approaches, and the structure failed shortly after its completion, on the approach of a moderate rise in the river. This work is described as technically successful.

Then one of the subsidiary water companies of the Imperial Valley offered to undertake the closing of the break, and they began operations about June 1, 1905. Their plan provided two rows of piling 15 ft. apart, to be filled in with brush and sand bags. They also failed to see the importance of protecting the approaches, and as their work advanced from one side the erosion of the opposite bank readily kept pace therewith, and the work was finally abandoned.

By this time sufficient water had reached Salton Sea to encroach on the Southern Pacific Railway, and necessitated moving portions of the track.

After the summer floods of 1905 had passed, a different plan was decided upon, and a third attempt was made to check the flow. This time a single-row pile dike wattled with brush was to be extended from the head of the island lying opposite to the intake to the right bank, the object being to silt up the channel on the west side of the island which carrried about two thirds of the total flow of the river. But the bottom rapidly eroded and undermined the piles, and another row of piles was started farther up the stream, with like results, and the work was again abandoned.

A fourth attempt was then made by a San Francisco contractor, in the construction of a pile and brush dam some 600 ft. long, to close the channel west of the island. The plans contemplated a mattress foundation for this dam. About a month after the dam was begun a flood from the Gila River destroyed the work and washed away the head of the island to a point considerably below the site of the dam, and the fourth attempt was added to the list of failures.

In the meantime a wooden A-frame head-gate was designed and located near the north bank of intake No. 3, which was now the main river, for the purpose of diverting the low-water flow through a by-pass and controlling the same by means of a gate. The structure was of ample capacity to pass the normal low-water flow, which would leave the work of closing the intake proper to be handled on dry ground, and on the completion of that work the gates were to be closed and the river would then be diverted to its old bed, which had become dry, as the entire volume now flowed to the Salton Sea.

This gate was known as the Rockwood gate. It was supported by some five hundred piles crossing the by-pass, which was 200 ft. wide. There were three lines of sheet piling and the bottom was covered with a plank floor 60 ft. in width. There were 40 openings, each 4 ft. in width, and the flow was controlled by means of flashboards. The construction of this gate was still in progress when the spring floods of 1906 put a stop to the work. The intake by this time had enlarged to a width of about 1 800 ft., and the erosion of its southern bank left the head-gate some 1 500 ft. inland, thus materially increasing the length of the by-pass required.

It may be well to say here that in handling this problem of

closure it was necessary to insure to the people of Imperial Valley a sufficient supply of water for their needs. So a complete closure would be as fatal on the one hand as an overflow on the other. Up to the present time they have had to face only the latter.

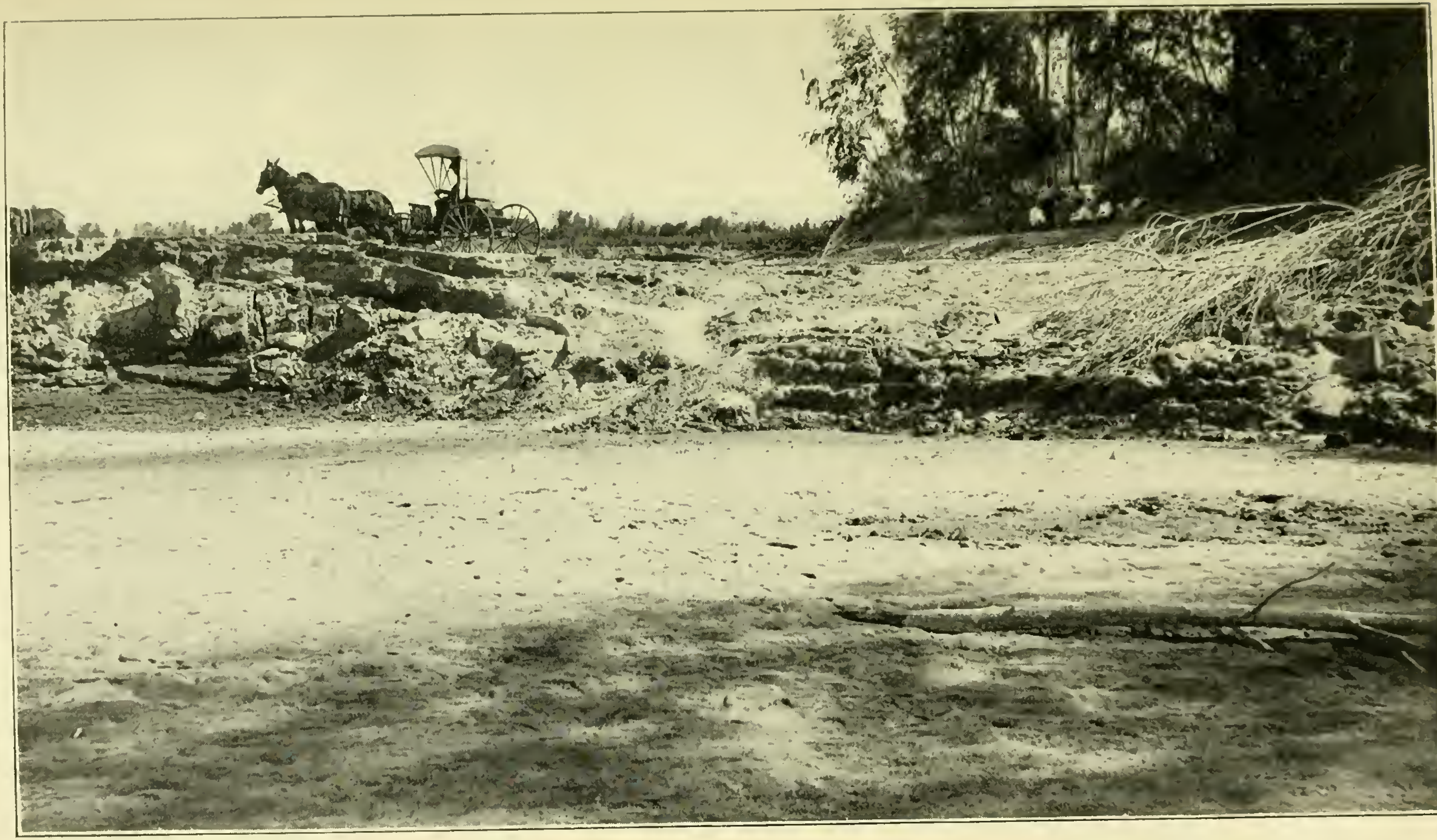
By this time it became apparent that permanent head-gates were essential to the success of the irrigation project, and such gates were designed and constructed a short distance north of the boundary line. This structure is made of reinforced concrete and has 11 gates of the Taintor type, 12 ft. wide and 10 ft. high. There is also a by-pass gate for skiffs and like craft. The capacity of these gates was estimated at 10 000 cu. ft. per second. One end and a portion of the base are founded on the solid rock. The river end terminates in the alluvial soil. Weight is added to the structure by filling the hollow spaces with gravel.

During the short interval these gates were in operation last November they silted up and filled with drift to such an extent as to threaten their usefulness.

The spring and summer floods of 1906 were unusually prolonged, and from March to June the break on intake No. 3 had widened from 500 ft. to 2 600 ft., and the surface of Salton Sea rose about 40 ft., which necessitated the rebuilding of about 40 miles of the main line of the Southern Pacific Railway, and a considerable portion of the Imperial Valley branch was badly damaged by being washed out.

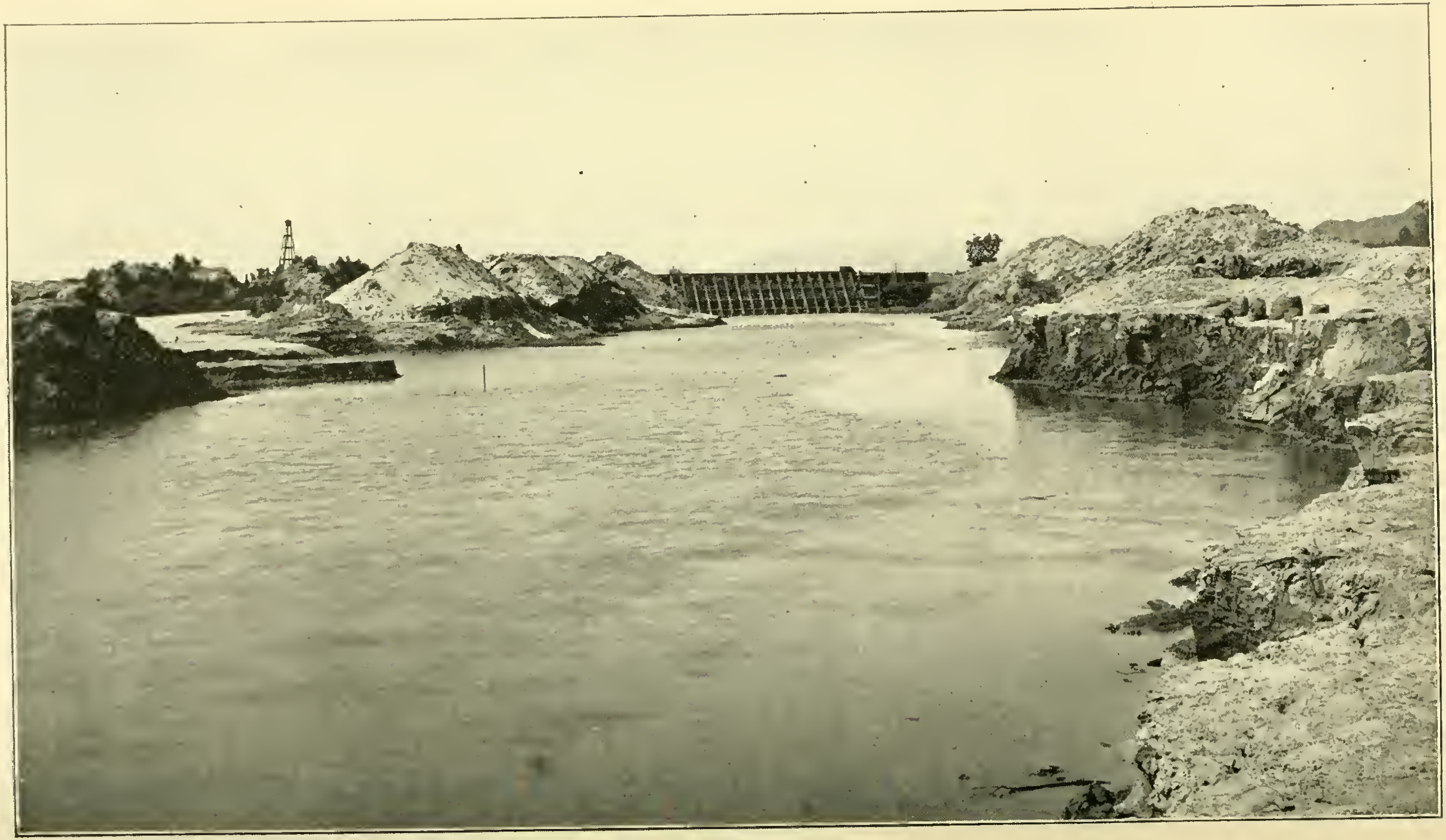
At this juncture the Southern Pacific management assumed charge of the work of closing the break, and the fifth attempt was begun in August, 1906. The plan this time was to build a solid dam entirely across the break, opening a by-pass so as to carry the low-water flow through the Rockwood gate. Some 2 000 ft. of the dry portion of the bed was simply an earthen embankment.

The flowing channel, 600 ft. in width, was cut off by a rock-fill dam on a mattress foundation 100 ft. wide and about 18 in. thick. A trestle carried a track across at such height as to permit of dumping material from the cars to the maximum elevation required. The equipment of the Southern Pacific Railway was drawn upon to a lavish extent, and the material, gravel and rock was filled in with great rapidity and in enormous quantities. All accessible quarries within 400 miles contributed stone, gotten out by an army of men. Hundreds of teams and more than a thousand men were engaged in the immediate vicinity of the dam, and the work was certainly rushed in an admirable manner.

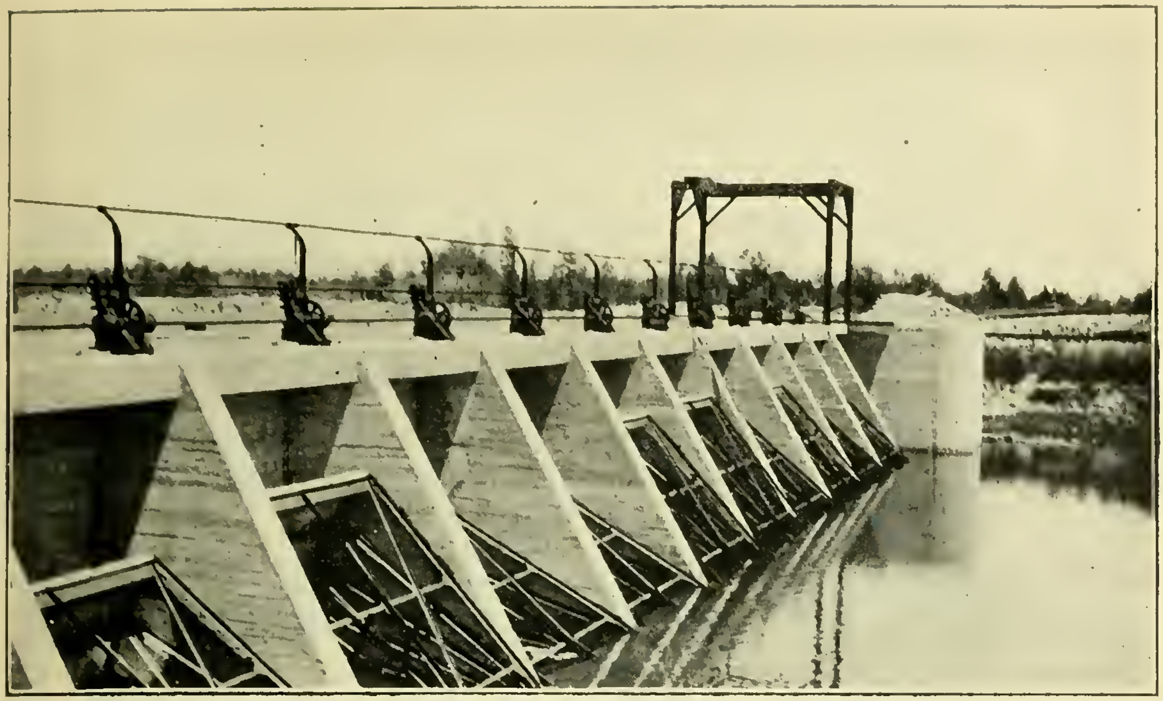


Buggy standing in the old bed of the Colorado River. The new bed in foreground shows at that point the extent of the depression of the new bed due to flow into Salton Sea.

PLATE 2.



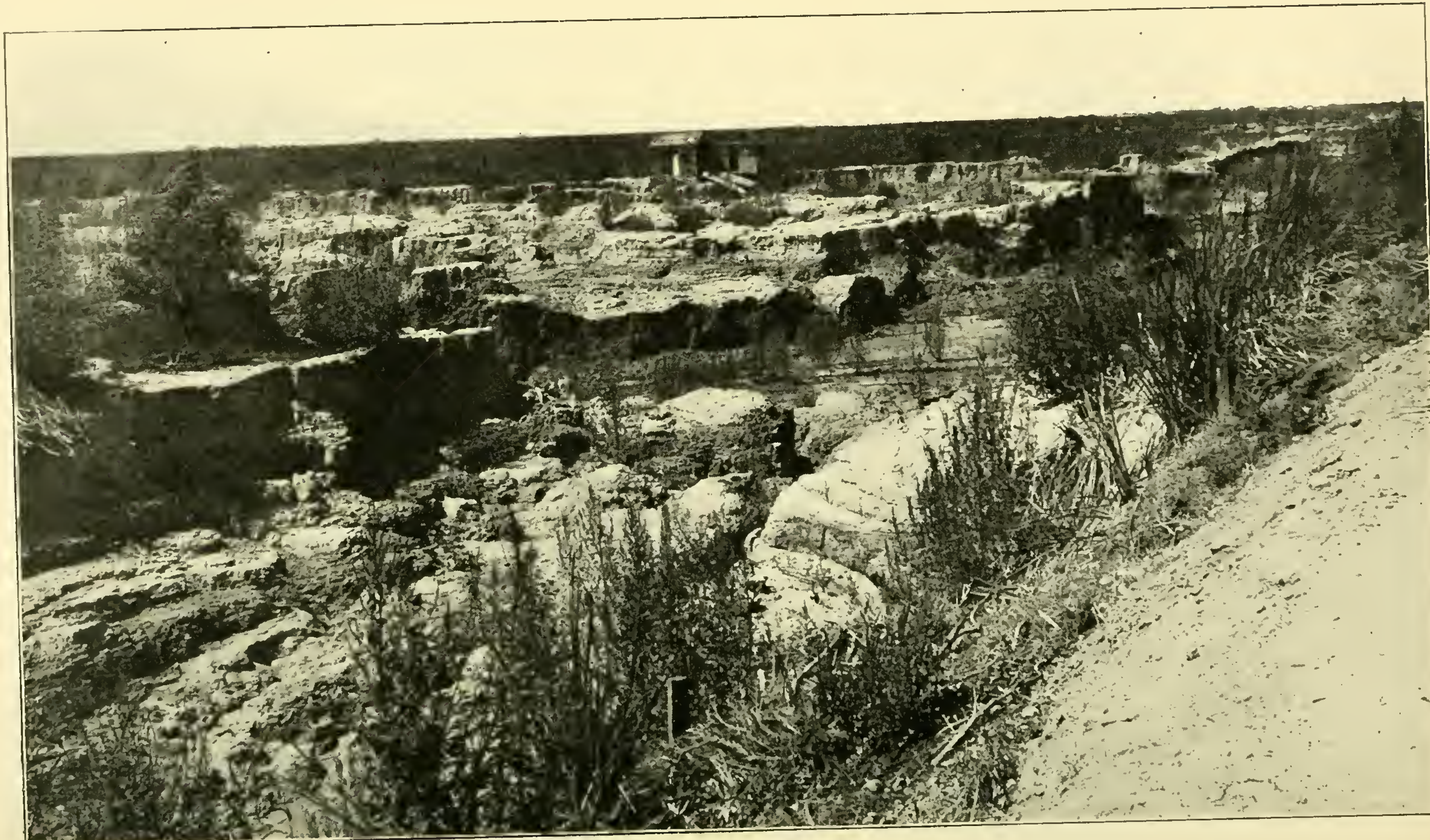
The Rockwood Head-Gate which was intended to control flow of Colorado River while the break was in process of closure. It failed at the critical moment and floated down stream. Taken August 26, 1906.



Concrete Head-Gates (Taintor Gates), Imperial Valley Canal.

Salton Sea: Part of Abandoned Track of Southern Pacific Railway. This point is 205 feet below sea level. Depot near by was moved three times to keep it above advancing flood. Taken August 26, 1906.

PLATE 4.



View showing the extraordinary amount of erosion of the surface of the ground in Imperial Valley caused by the water rushing through the Colorado River break toward Salton Sea.

Rock and gravel were dumped in until the water level was raised about 6 ft. on the upper side of the dam, and the whole flow was then diverted to the by-pass through the Rockwood gate. Success seemed assured, but a slight rise in the river, accompanied by drift, choked up the gate, and erosion of the by-pass, for which no protection had been provided, became alarmingly active and an effort was made to check it by dumping in rock above the gate. While this was going on, about 120 ft. of the gate suddenly rose up and floated off, and in a short time the river was again free from control, and continued on its way to the Salton Sea without hindrance. This was wholly unexpected, and those in charge who had been so confident of good results were now thoroughly discouraged.

The channel across which the dam was partially completed was dry, and the problem of closure was transferred to the by-pass.

There was no time for delay, and the sixth attempt to divert the river was promptly inaugurated. The entire force was turned toward the closure of the by-pass by means of three parallel rock-fill dams, each sustaining a portion of the head. These were raised gradually until the water was finally shut out and diverted over the dam proper. Then, with an extraordinary burst of energy, the entire line was raised, and on the 4th day of November, 1906, the water began flowing down the old bed of the river toward the Gulf of California, and twenty days later the closure was complete.

While this work was in progress a tremendous amount of material was handled and a shortage of cars on that work at least was unheard of. Over two hundred carloads of stone per day was no unusual amount to handle. The rock came on flat cars and the blocks were sometimes too large to move by hand, and they were then broken up with dynamite as they lay on the cars.

The concrete head-gates were put into commission, and Imperial Valley was supplied with water again under control. Levees were completed from the upper head works down to the dam and below the same for a considerable distance in order to prevent the floods from overtopping the natural banks of the river.

The sixth attempt at closure was apparently successful, and great rejoicing prevailed among the people of Imperial Valley whose fate had been trembling in the balance for more than two years. The newspapers at the time announced in bold

headlines, " Long period of suspense is over. Closure of break in river effected. The only thing the people of the Imperial Valley now have to worry about is the fact that they have nothing to worry about."

But they were again doomed to disappointment. In less than a month the river had once more abandoned its old bed for the more attractive route to the Salton Sea.

The closure works were still regarded as technically successful, because the new break occurred at a point some 1 200 ft. south of the end of the dam; the results, however, were far from satisfactory to the people of Imperial Valley.

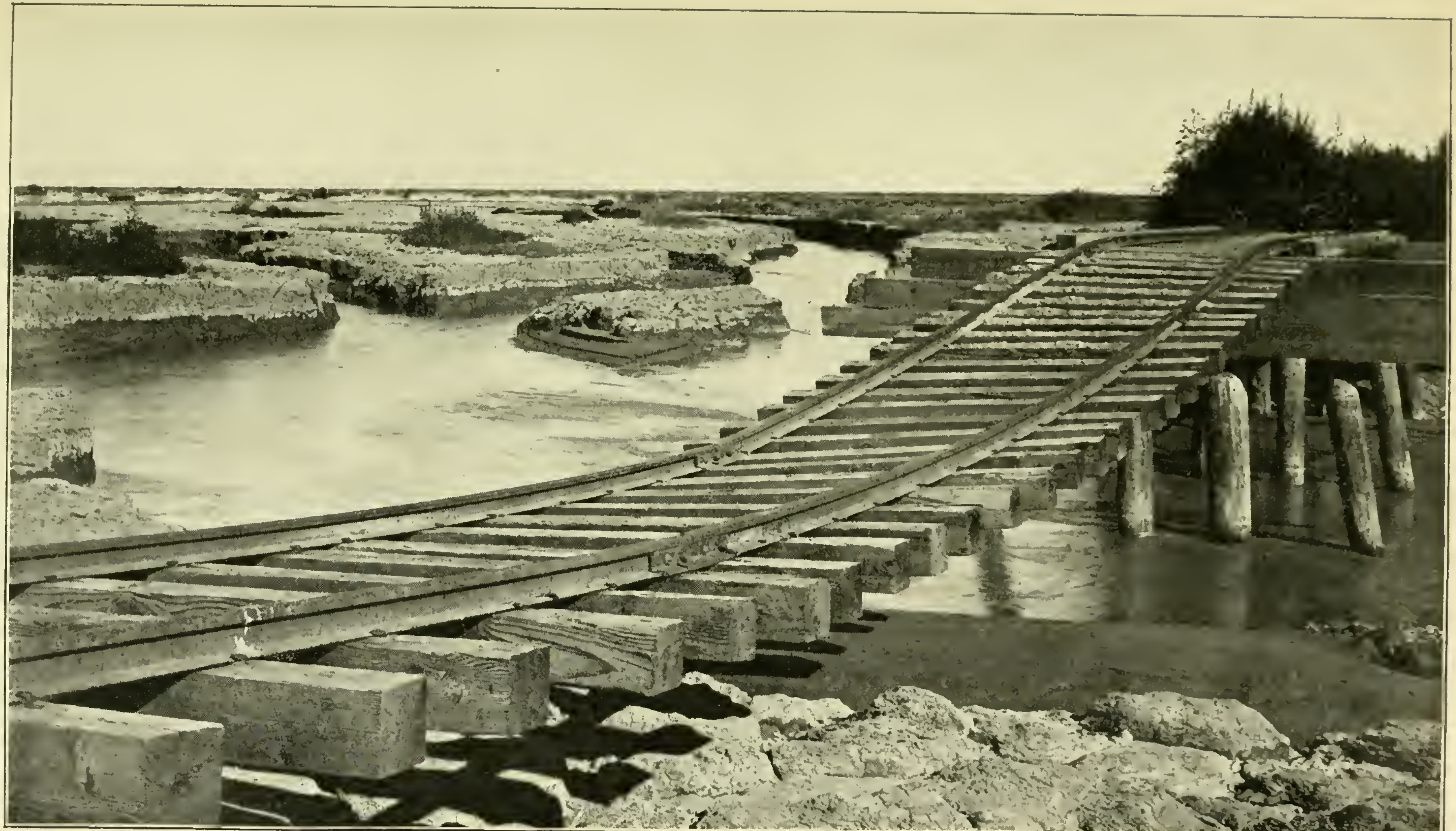
The last break was clearly attributable to defective levee construction. With water only about 1 ft. above the natural surface of the ground, several leaks developed through the natural soil, which gave way beneath the levee, and before means could be taken to stop it, earth and levee crumbled, and again the river broke away fom its captors and resumed its work of filling up Salton Sea.

As a foundation for a levee the soil is extremely treacherous, being porous and filled with cracks, roots and drift. In spite of this fact, even the ordinary precautions used in levee building with far better material were wholly neglected. One glaring defect was that of having the borrow pit on the land side of the levee. Under such conditions, failure was more than probable.

It is said that over two million dollars had been expended up to this time in the various attempts to divert the Colorado River to its former bed. A vast amount of damage had been done in Imperial Valley to the towns, farms and homes of the inhabitants. The Southern Pacific Railway suffered great loss in the submergence of its tracks. Some 8 000 to 10 000 people in the Valley were in distress, sadly discouraged and helpless. An appeal was made to the general government, which was promptly responded to by our worthy President, who, in a message to Congress, urged the passage of a measure providing funds for making a permanent closure of the break.

In the meantime but a very short period of the low-water season remained in which to complete another closure, and the organization, equipment and the credit of the Southern Pacific Railway again came to the rescue, and the seventh attempt to turn the Colorado River through its old channel to the Gulf of California was promptly begun.

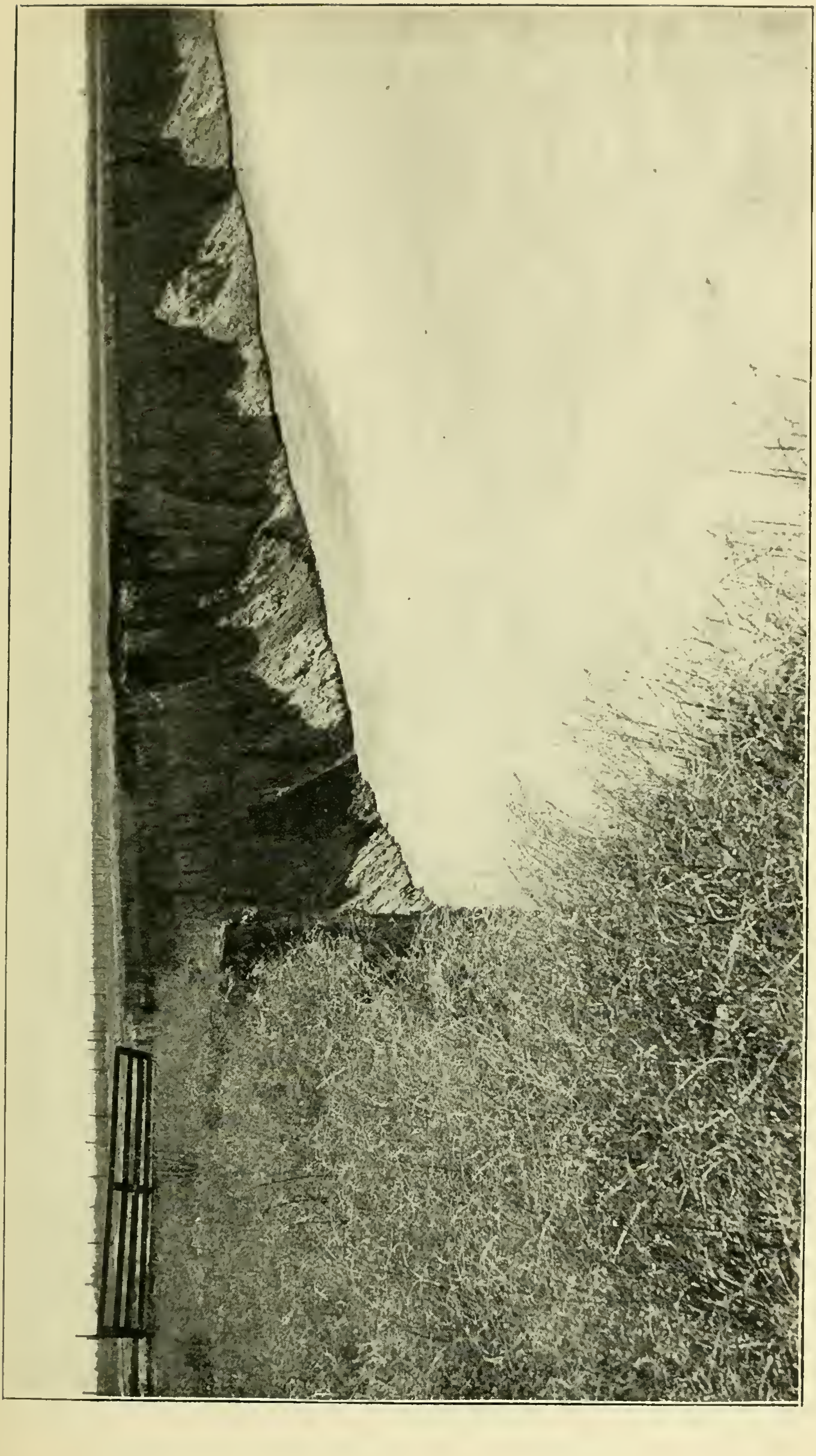
The work was done under many difficulties. Unexpected floods, ranging in volume from 30 000 to 50 000 cu. ft. per sec-



View showing how surface of ground in Imperial Valley was washed into gullies by Colorado River water rushing toward Salton Sea. Taken September 1, 1906.

PLATE 6.

This view shows the head of channel formed by gathering of numerous small streams from the Colorado River break, all on their way toward Salton Sea. Also shows how the surface of the ground was eroded by the rushing water.



View showing banks of New River, 4½ miles northwest from Brawley, Cal. Banks caving away very rapidly. Taken August 30, 1906.

PLATE 8.

View showing erosion of the banks of New River in Imperial Valley, due to the Colorado River break and water flowing to Salton Sea.

ond, demolished the trestle four different times, but the lower trestle was finally completed and a second trestle was constructed across the break about 50 ft. above it. Active dumping of material from the lower trestle was then begun, and in 14 days and 6 hr. a rock-fill dam was completed, and the Colorado River, on February 11, 1907, was again flowing seaward through its old channel, and the intake route to Salton Sea became practically dry.

In the first twelve hours of the work 7 000 cu. yd. of heavy rock was placed in the dam, and a total of 2 200 carloads of material was required to complete it. No foundation mat was used, reliance being placed in the ability to dump material so fast that the settlement would not materially retard the completion of the work. The dam sustained a head of some 13 ft. before the flow was diverted to the old channel, the bed of which was much higher than the bed of the intake, owing to the depression of the latter channel due to the greatly increased slope to the Salton Sink. The volume of flow during the progress of the work ranged from 15 000 to 20 000 cu. ft. per second.

The reconstruction of the levees, to eliminate the defects developed by the previous break, was also actively carried on, and it is hoped that the work done may successfully resist the spring floods.

As an emergency work, the situation has been handled in a masterly manner, regardless of cost, by the management of the Southern Pacific Railway and its engineers. It is evident, however, that a properly developed scheme for the irrigation of the Imperial Valley in the beginning would, in all probability, have obviated the necessity for such a tremendous waste of energy and money.

The Colorado River has a watershed covering an area of 225 000 sq. miles, and the discharge at Yuma ranges from 3 500 cu. ft. per second at extremely low water, to 200 000 cu. ft. per second at maximum stages. Immediately above the break, normal slope of the river is about 1 ft. per mile.

The water at the break leaves the river at an elevation of 130 ft. above sea level, and when the flow to Salton Sink began it had a fall of over 400 ft. in a distance of about 90 miles. Flowing as it did over very loose, fine, alluvial soil with such an excessive slope, it first created havoc with the surface of the ground before gathering into defined channels, and then developed great chasms. In one case the gorge was eroded to a depth of 80 ft. and 1 300 ft. in width, with a vertical cataract

that moved upstream at a maximum rate of nearly 4 600 ft. in a day. This cataract was the most alarming feature of the whole situation, as it was realized that if it should once reach the bed of the Colorado River proper, a diversion of that stream to its former bed would be practically out of the question. It would also move very rapidly upstream to the Laguna Dam, under construction by the government, and it would be quickly destroyed. The Imperial Valley would be rendered uninhabitable, both on account of its gradual submergence by the filling up of Salton Sea and the difficulty of securing water for irrigation purposes from the depths of the gorge, far below the surface of the lands.

The Southern Pacific Railway would be forced to construct, at great cost, about 80 miles of new track through the rugged foot hills.

Leaving out the value of the annual production of the valley for future years, the loss incident to the Colorado break, if not brought under control, has been estimated at a hundred million dollars.

There are advocates who recommend that this destruction should be permitted to go on, in order that a great lake may be formed, which, it is claimed, would increase the rainfall of the surrounding country for a distance of several hundred miles. The legislators of Utah and Texas, with this in view, petitioned Congress to allow the basin to fill up.

In order to show that these ideas are wholly erroneous, it is only necessary to call attention to the fact that the Gulf of California, similarly situated, and many times the area of the Salton Sea, is only about a hundred miles distant.

From the best obtainable data it appears that the evaporation from a reservoir in that climate amounts to about 7 ft. per annum. Salton Sea might reach an ultimate area of something less than 1 900 sq. miles if the river continued to flow into it. People in Texas and Indian Territory, 800 miles away, claim to be feeling the beneficial effects of added rainfall already. The area at the present time is something like 400 sq. miles, and the normal evaporation therefrom would give an average of 1 ft. of rainfall per annum over an area of about 2 800 sq. miles. Unless there is some special attraction in the localities named, it does not seem probable that any portion of the water evaporated from the Salton Sea ever reaches them. If it does, then the Gulf of California, which is even nearer, should provide an ample rainfall at all times.

One writer suggests that the filling of the basin should be allowed to go on, and even be hastened by cutting a channel from the Gulf of California, in order that it might be used for purposes of navigation, and also exercise a beneficial influence on the arid regions of the United States.

If allowed to flow, the area of the sea would reach about 1 900 sq. miles in something like fifty years' time. At that stage the annual evaporation would practically equal the annual discharge of the Colorado River, and the surface would never become high enough to flow over the barrier into the Gulf of California unless the deposits of the Colorado should build up a new delta of such proportions as to change the direction of the flow. The annual volume of sediment brought down by the Colorado River is estimated at over 50 000 000 cu. yd.

With the supply of water cut off by the closure of the break, the water now in the Salton Sea will evaporate in about ten or twelve years.

I am greatly indebted to Mr. H. T. Cory, in local charge of the closure work, and the engineers of the United States Reclamation Service for courtesies extended during my visits and for data furnished me at later date.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1907, for publication in a subsequent number of the JOURNAL.]

THE HARVEY CANAL AND LOCK.

By Gervais Lombard, Member of the Louisiana Engineering Society.

[Read before the Society, October 9, 1905.]

Some ninety years ago, Mr. N. N. Destrehan, a wealthy planter living on the banks of the Mississippi River, just opposite the city of New Orleans, carried out what at that time was considered a gigantic undertaking. He dug what he intended for a drainage canal beginning at a point opposite New Orleans adjacent to the Mississippi River, but separated therefrom by the river's right bank and extending about five miles southerly to deep water in Bayou Barataria. This canal was dug by hand, Mr. Destrehan employing several scores of slaves to do the work. As the slaves were only employed on the canal work when not otherwise busy with the plantation work, several years were required to complete it.

At first this canal was dug only 12 ft. wide, and the grade of the bottom was but 3 ft. below mean gulf level. From time to time it was slightly enlarged, as it was found that it could be used as a navigation canal; and the story goes that Lafitte, the pirate, often made use of this canal. Most of the transportation then was in luggers and boats of light draft, and a vast area was reached by means of this canal via Bayou Barataria with its multitude of ramified waterways.

In the year 1858 the canal was dredged to a width of 60 ft. by the Harveys, who had inherited the property. At first the chief traffic was in oysters and the fishery industries; but the time came when cypress timber and agricultural products from the higher banks of Bayou Barataria, Bayou Lafourche and the other streams grew to such proportions that it was decided to connect the canal directly with the Mississippi River by means of a lock.

So in 1882 work was commenced on the lock, which was completed within a year. However, it was found, when this lock was tested, that it failed to hold a head of even 14 ft. It was believed at that time that the failure of the lock was due to faulty construction and the use of inferior cement in the masonry. The brick masonry settled and cracked, and the water went under the flooring of the gates, threatening disaster

from overflow when the Mississippi River was at flood stage. The lock was promptly condemned by the levee and railroad authorities, and the canal was dammed across its mouth with an earthen dike. The canal proper, however, was enlarged to a width of between 50 and 60 ft. for its entire length, and is still used by sailboats, steam and motor craft for bringing rafts, fish and produce to the banks of the river, where the cargoes are transferred over the levee to boats in the river, or hauled by wagons, which are ferried across to the city of New Orleans.

In the meantime, Company Canal, which was excavated about the year 1830, and which is located several miles above Harvey, leading from the river at Westwego back to this same system of waterways, had been successfully locked, connecting it with the Mississippi River. In 1902, the Harvey interests were incorporated into a stock company, known as the Harvey Canal Land and Improvement Company, and the lock project again undertaken, as it was found that ample business was in store for both canal companies. A contract was let to enlarge the canal for two miles nearest the river to a width of 80 ft. and to a depth of 7 ft. below lowest canal level. This gave ample room to handle the large rafts being brought to the Louisiana Cypress Lumber Company without interfering with the vessels.

Mr. R. E. DeBuys, a member of the Louisiana Engineering Society, was retained as engineer in charge, and he designed the new lock. The location was fixed by the canal company adjacent to and immediately in the rear of the original lock, no part of which was to be used in the new lock. Only two test borings were made, one near each gate. The information thus gleaned showed that where the front gate was to be located there was nothing but fine gray sand (quicksand) for a depth of 81 ft. below the natural surface of the ground, with the exception of one or two streaks of sand mixed with blue clay, the nearest of which was 38 ft. below the floor of the gate. Notwithstanding this fact, the company directed the work to proceed on the location already selected by it. The boring near the rear gate location showed a thick stratum of hard blue clay for a depth of 63 ft. before quicksand was encountered.

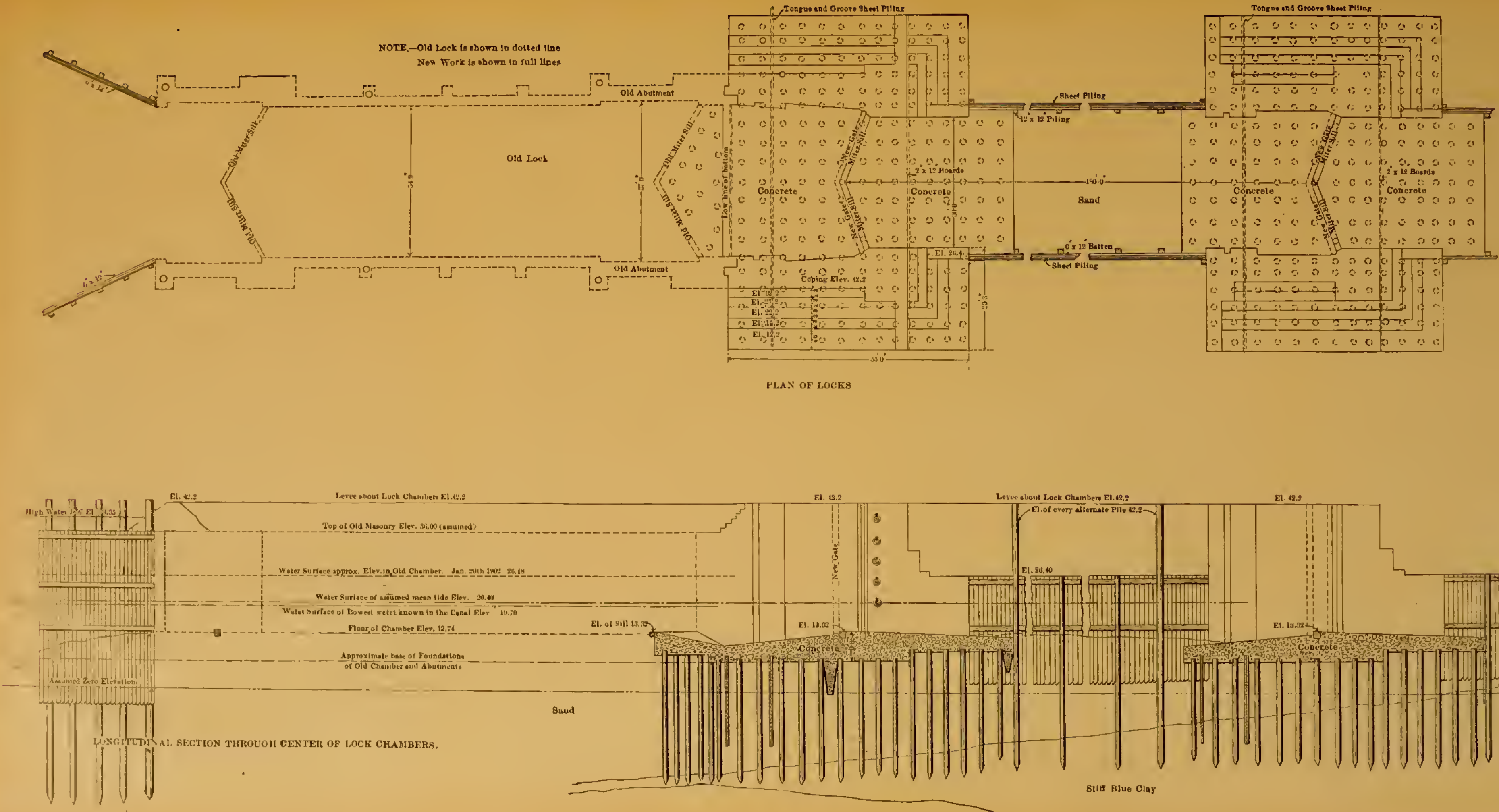
As will be seen from the plan, the old masonry lock chamber and gate abutments serve as a forebay approach to the new lock. There could be no salvage from the old lock, as the gates, though steel, were badly corroded by rust, and had been designed to stand a fluctuation of only 12 to 14 ft. in the river,

while, owing to new conditions, a head of 19 to 22 ft. had to be provided for at this time. The water surface in the canal varies but little comparatively and remains within a few inches of mean gulf level, seldom fluctuating more than 3 ft., due to tides in the gulf, except in times of overflow, when crevasses occur in the levee line on the banks of the Mississippi River above or below the site of the lock. The river, however, has a fluctuation at this point of about 19 ft. from the lowest to the highest water mark, and it is estimated that when all the outlets to the Mississippi River have been closed and the levee line held all the way on both sides, at least another foot of water may be expected.

The sills of the old gate were eight (8) ft. below ordinary canal level, and, as the old lock had a clear width of 34 ft. 9 in., while the new lock is only to have a width of 30 ft. 6 in., said old lock was not wrecked or cleared away, but left, as stated above, to serve as an approach. The miter sill of the new front gate is 7 ft. below ordinary canal tide, and the sill of the new rear gate is 1 ft. lower. The reason for elevating the front sill was that for the greater part of the year there is a head of more than 1 ft. from the river and that the deeper draft boats which could just pass over the rear sill could almost always be floated over the front sill.

As is the case in all this region, no bed rock was within reach, so reliance had to be placed on piling. Round piles, 45 ft. long and not less than 15 in. in diameter at the butt end, and not less than 8 in. in diameter at the blossom end, were used. These piles were spaced 4 ft. centers generally, with closer spacing under the quoin posts and heavier portions of the lock.

When the writer was retained as engineer in charge, vice Mr. De Buys, who could no longer act in that capacity, due to press of his architectural work, to which he desired to devote his entire time and attention, the pile foundation for the front gate had been practically completed, and most of the sheet piles were already driven. The work was being done by the company itself, with Mr. Louis Lesassier as superintendent. This arrangement had been determined upon after sealed proposals had been received and all rejected as too high. The only changes made in the plans after the writer assumed charge were minor and consisted chiefly in additional precautions to prevent the water from displacing the earth beneath the floor of the lock and around the abutments. The transverse rows of sheet piling were lengthened to 25 ft., and two cores of concrete were placed



LONGITUDINAL SECTION THROUGH CENTER OF LOCK CHAMBERS.

wh
pr
bu
me
in
the
lov
thi
ma
sip
on

ca
wh
loc
to
is
ga
th
1 f
jus
th

rea
45
an
us
clo
loc

Mi
pr
en
ha
ali
its
me
rec
in
co
fro
ar
we

beneath as shown on the section. This was done to prevent the water from having a straight flow along the underside of the flooring in case any should get through the sheet piles. Similar concrete offsets were also placed on the vertical land faces of the abutments so as to insure a safer bond between the concrete blocks and the earthwork forming the levee. Reverting to the foundations, after the round piles had been driven and the cofferdam built (a row of triple lap wooden sheet piling entirely around the group), the earth was excavated to a depth of 1 ft. below the cut-off grade of the round piles. To the heads of these round piles were driftbolted and strapped 12 in. by 12 in. caps, transversely, some of which extended clear across the floor and under the heavy abutments or walls. Concrete, consisting of one part Illinois steel Puzzolan cement to three parts of sharp sand and five parts of washed gravel, and reinforced with corrugated steel bars, was then filled in to the top of the caps, thus giving a solid floor 2 ft. thick. The span is 30 ft. 6 in. in the clear between walls, and for that width the floor was sheathed with a double thickness of 3- and 4-in. pine boards laid on the oblique and spiked to the caps. The miter sills, of course, were not only bolted to the heads of the piles they rested upon, but were married into the concrete flooring. Fifteen-inch by 18-in. white oak sills were sought, but not being available, a good quality of long-leaf yellow pine was substituted. The ends of the miter sills extend several feet under the concrete walls, and the faces with which the steel gates are to be in contact, when closed, were sheathed with a strip of steel 6 in. by $\frac{5}{8}$ in. The spread at the foot of the walls is 20 to 23.5 ft., and the width of the walls is narrowed by offsets until they are but 6.5 to 12 ft. wide at the top.

Each gate is, therefore, swung on a concrete monolith containing nearly 1 200 cu. yd. Steel Puzzolan cement was used for all that portion of the concrete which was below ordinary canal level, and the "Universal" brand from the low-water line up. The concrete blocks were reinforced with long wrought-iron bolts placed vertically at intervals and having wide flanges or plates under head and nut. As the concrete work progressed, bolts for snubbing hooks, anchorage to hollow quoins and the gates were built in.

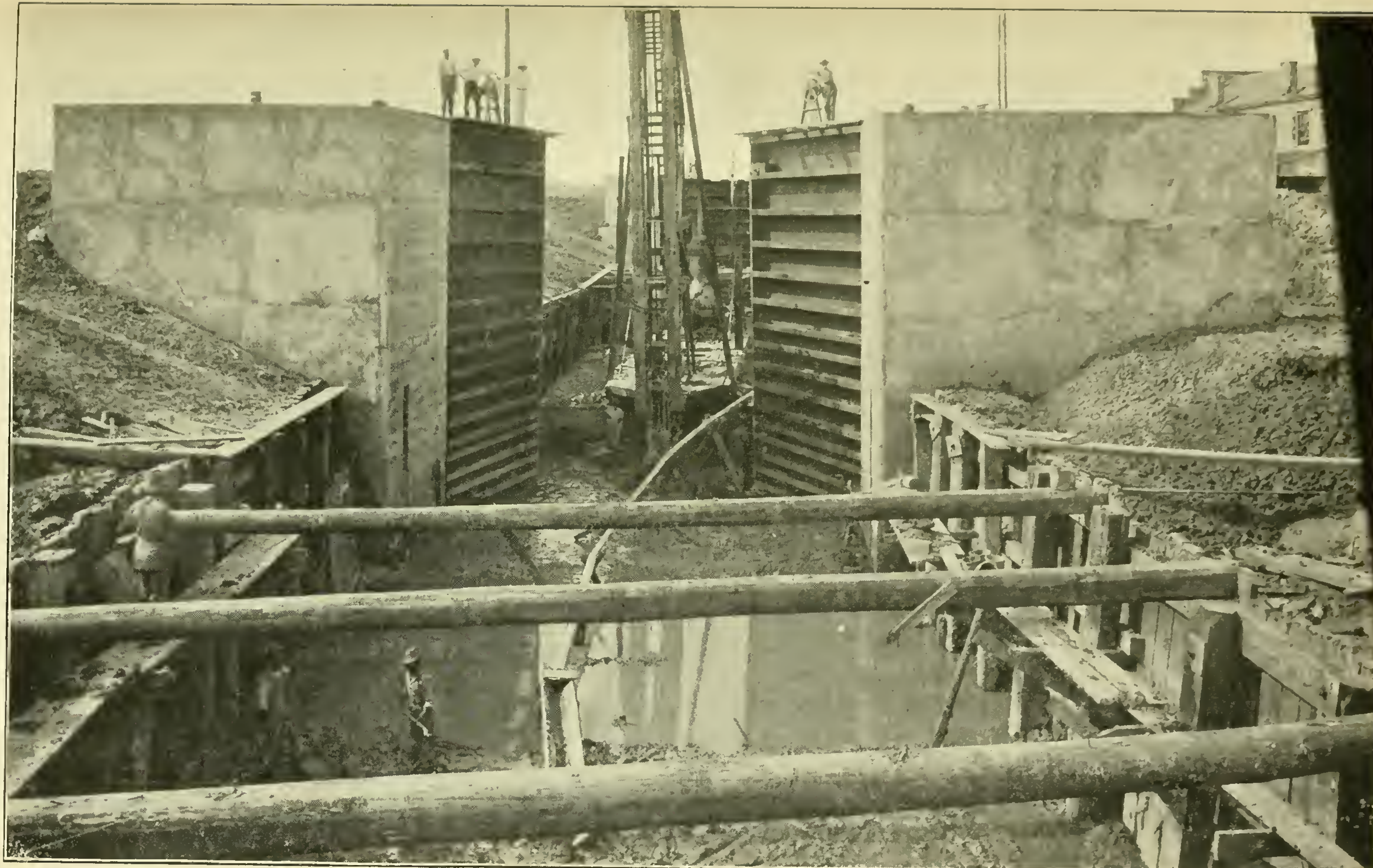
The chamber between the gates is 180 ft. long, and the retaining walls consist of a triple lap pile bulkhead rising about 4 ft. above mean canal level and back filled with earth well sodded with Bermuda grass and sloping to the crest of the levee

with a slope of three horizontal to one vertical. The levee is of the standard type built along the Mississippi River, having a crown 8 ft. wide and slopes of 3 to 1 on each side, and being 3 ft. above the highest water in the river. It is built of clay and sand carefully sorted so as to exclude all wood, brick, trash and foreign material of any character.

The gates are of steel, and as the miter sill is pitched 6 ft. in 16 ft., each gate is 17 ft. 5 in. wide by 29 ft. 3.625 in. in height by 15 in. in thickness. Near the bottom of the gates, where the water pressure will be greatest, the 15-in. I-beams which form the ribs of the gate are spaced only 1 ft. 3 in. apart, and weigh 52 lb. to the running foot; while near the top of the gates they are spaced 3 ft. apart and weigh 42 lb. The irregular spacing near the bottom is due to the location of the wickets of the valves, which are in the gate proper and by means of which the water level is controlled. The skin plates are placed on the river side only and are 0.1875 in. thick. The wickets are comparatively large, having double sluices each 1 ft. by 3 ft. The effect of such large valves, while permitting rapid locking, is to cause considerable swirl and wash behind each gate, which had to be taken care of by a pile bulkhead on each side of the canal for some distance back of each gate, and a wooden flooring extending about 60 ft. back of the gates.

The opening apparatus is of the same type as that used at the Lake Borgne canal lock, namely, a stiffened I-beam made fast several feet below the top of the gate and forced forwards or backwards by means of a worm working into a row of cogs on the I-beam and operated by a hand crank mounted on the concrete blocks.

The quoin posts are hollow, and consist of a vertical I-beam 15 in. @ 50 lb. riveted to each rib of the gate and to the skin plates. Opposite the end of each I-beam are ribs or spreader plates which act as stiffeners to the quoin posts. The skin plates of the quoin posts are polished steel, 0.25 in. in thickness. The quoin posts are eccentric in shape. When seated on the pintles and swung by the opening apparatus, the motion of the post being eccentric to the hollow quoin, friction is rapidly removed, and the post touches nothing but the stirrup at its head and the pintail at its foot after the gate has been opened only a few inches. In order to secure a closer contact between the quoin post and the hollow quoin when the gate was closed, the writer had the pintle reduced in diameter slightly, allowing some play so that the pressure would be sure to jam the gate against the



View Looking Northward.

hollow quoin and prevent leakage. It was feared that too nice a fit would be necessary if no play were allowed, and the fact that the eccentric motion opened a space between the hollow quoin and the quoin post sufficiently wide to accommodate drift and trash, so common in the river and canal water, made some play essential as a safety measure. The wickets are operated by means of a double-geared hand crank, mounted on an "A" frame. The jamb of the gates consists of a beveled cypress stick, nicely fitted and bolted into the channel bar, forming the jamb edge of the gate. The anchorage for the head of the quoin post is quite simple. The pin at the head of the quoin post revolves in a brass bushing seated in an assembly plate which is so arranged as to be easily adjusted. This assembly plate is in turn anchored back with two 0.75 in. upset rods, which are made fast in an iron casting designed for the purpose and securely bolted into the concrete block.

To accommodate the traffic which until now had crossed the canal on the dam near the head of the canal, it became necessary to provide a traffic bridge. The Means & Fulton Iron Works, of Birmingham, Ala., who furnished and assembled the steel gates, also furnished the girder bridge, which was placed 90 ft. in the rear of the rear gate. The foundation of the pier upon which the bridge is turned consists of a cluster of round piles 30 ft. long and spaced 2.5 ft. centers. The piles are cut off to a grade 8 ft. below the lowest water. No caps were used on the heads of these piles, and the concrete was placed directly on them, commencing 1 ft. below the cut-off grade.

The concrete in the pier foundation is reinforced with corrugated steel bars and forms a cylindrical block 14 ft. in diameter and 13 ft. in depth. The bridge is seated upon a truck which rides a circular track and is operated by a ratchet and pinion. The bridge turns on a pivot. The bridge span is 35 ft. in the clear and when closed the ends rest upon substantial concrete shore piers with pile foundations. The roadway is 14 ft. in the clear. The main girders are 70 ft. long, with 0.25 in. web 3 ft. 4 in. high. The joists are 6 in. by 15 in. wooden beams, spaced 4 ft. centers resting directly on the lower flanges of the main girders. This bridge is calculated to stand a dead load of 725 lb. per square foot, a live load of 100 lb. per square foot, a concentrated load equal to a 15-ton road roller with 6 tons in front roller and 9 tons in rear roller, and a wind pressure of 30 lb. to the square foot. The unit stresses required were: Tension girder, 15 000 lb. per square inch; rolled beams, 16 000, and braces

20 000. The web is required to stand a shearing strain of 6 000 lb. per square inch.

The lock was completed in August, 1905, and the official tests prescribed by the Board of Commissioners for the Lafourche basin levee district were started, but the front gate failed, due to the water running under the foundation where the quicksand offered insufficient resistance to water pressure due to a 17.5 ft. head. A 19 ft. head had been prescribed, which had to be maintained for six consecutive hours without showing material leakage. The water in the forebay was still being raised when the failure occurred. As the back gate was ready for test, it was tested by having the water behind the gate pumped down to the floor level, while a head of 19 ft. was placed against the gate. The earthwork adjacent to the concrete blocks was thoroughly wet and allowed to settle for several days, and the water was pumped slowly against the gate, requiring two days to reach the maximum head of 19 ft. The maximum stage was maintained for 6 hr. with no leakage of any consequence developing. The wickets and the opening apparatus were also tested and found to operate satisfactorily. Each gate had to be given two tests, the first with a head of 19 ft. against the front of the gate, and the water behind the gate pumped down to floor level; and the second with water at canal level behind the gate and 19 ft. higher in front. The rear gate was only given the first test, it being decided to make the second test when the front gate was repaired.

The front gate was not wrecked in any way by the failure, except that the earth blew out from under it. The concrete monolith remained intact and no settlement took place, as the concrete rests on the piles which did not move. The failure was, no doubt, due to some defect in the cross rows of sheet piling which were driven into the quicksand with difficulty and must have pulled open sufficiently to let the water pressure through directly against the quicksand under the floor.

The writer recommended replacing the material which was blown out under the flooring with cement grouting, and the cutting off of any leakage under the lock by means of a transverse row of interlocking steel sheet piling, reaching the thin stratum of clay 38 ft. below the flooring and being married into the concrete at its head; the row of piles to be driven immediately along the front or river edge of the concrete work, and to extend clear across the lock and well underneath the levees on each side.

For several months the company debated the question as to whether it would not be safer to abandon the front gate altogether and build a third gate farther back than to attempt the repair of the front gate. It was even suggested that, instead of using the interlocking steel sheet piling recommended by the writer, the quicksand foundation be "set" by driving perforated pipes at stated intervals vertically under the floor of the lock and forcing cement grout into the sand. The writer sought the most authentic information in regard to the use of this method of curing trouble with quicksand foundations, and came to the conclusion that the method would prove more expensive, be more uncertain and require a greater length of time than the remedy already prescribed. Col. F. M. Kerr, chief state engineer of Louisiana, was called into conference and concurred with the engineer in charge.

It was, therefore, decided to follow the recommendation of the engineer in charge in regard to the use of interlocking steel sheet piling. It was then too late to undertake the repair work until after the high-water season of 1905–6, as the pit would have been too close to the river. So work was not started until August, 1906. The work was let by contract and has only recently been completed. The contractor experienced great difficulty in driving the interlocking steel sheet piles, which were of the United States Steel Pile Company type, 38 ft. long, 12 in. wide and weighing 40 lb. to the square foot. The fault was not due to the piles, however, but to the existing conditions, the quicksand and the method of driving the piles. The concrete retaining walls which joined the abutments of the new gate to the old masonry abutments had to be removed by drilling and blasting. That they had been well built was evidenced by the hard work required to cut through them. The trench was then nearly 30 ft. deep in places. The driver had to operate from above the top of the abutments.

The contractor first trenched but a few feet and attempted to use a follower pile through the unexcavated earth. The steel piles, being 38 ft. long, were found to be limber enough to give some trouble in driving them through the unyielding quicksand. A Vulcan No. 1 steam hammer weighing 10 000 lb. was used, and pendulum leads were employed for a part of the time. The engineer in charge refused to allow the contractor the use of a water jet except as a matter of last resort, so the contractor hammered away until the heads of the steel piles were severely battered. The special follower head which had been provided

by the company was discarded by the contractor, as in order to gain stiffness he set up three piles at a time, and these stiffeners were in the way of the follower head. He used a follower head of his own design, namely, a steel plate with angle irons bolted to its under side so as to fit over the web of the sheet pile, while the plate itself rested on the stiffer parts of the pile head. After working for many days, only thirteen piles had been driven to grade, and during the absence of the engineer in charge the contractor abandoned five of the piles which had been only partly driven, and proceeded to interlock and drive more piles further ahead in the hope that they would be found to drive easier and that he could afterwards get permission to drive the five abandoned piles with the aid of a jet. When the engineer in charge returned he found that the contractor had succeeded in driving several piles beyond the five abandoned piles without the use of the jet, and that the wooden half-round calking strips called for in the specifications had been crushed and broomed during the process of driving and allowed to accumulate at the head of the piles, while none of it reached the foot of the piles. The consequence was that the heads of the piles were wedged apart as far as the play of the ball and socket joint allowed, while the feet of the piles were squeezed together. This had given a slight batter to the last few piles driven as compared to the first piles driven, and the space left vacant beneath the five partially driven piles was encroached upon to such an extent that there was not room left for all five piles. In fact, the contractor had gone back to the five piles and hammered them until they were completely locked and jammed, with no hope of either pulling them up or driving them down. He could not even budge the end piles, which were free except for the clinging resistance of the quicksand. A 0.75 in. new wire cable was snapped in an attempt to pull up a 12 in. by 12 in. follower pile which had only been driven 6 ft. into the quicksand. So the attempt to pull the piles up was abandoned and the contractor agreed to blanket the space by driving in front of same Wakefield sheet piles. He failed to drive them even as far as the sheet piles went, even with the use of the jet. As this part of the row of sheet piles was beyond the outer foot of the up-stream abutment it was decided to leave the five partially-driven piles as they were and proceed with the driving of the continuous row of interlocking piles, in the hope that the bulk and weight of the big earth fill constituting the levee over this part of the row would relieve the necessity of driving these five piles all the way down to grade. So great

was the resistance to driving the remaining piles that authority had to be granted the contractor to use a jet. Great caution was exercised not to jet any more than was absolutely necessary. Jetting one pile part of the way down proved sufficient to not only enable the contractor to drive that pile down all the way, but to drive two or three more piles before it again became necessary to use the jet. Five or six piles per day was as much as could be driven under the circumstances.

When the entire row of one hundred sheet piles had been driven to grade, with the exception of the five piles mentioned above, the heads of the piles were married into the concrete floor and abutments so as to cut off seepage or direct flow under the floor. Then several holes were cut through the concrete floor of the lock, on the river side of the miter sill, and a short joint of 8-in. iron pipe was placed in each, with a flange at the top just flush with the surface of the floor. These were set in concrete so as to be left in place after they had been used to fill the voids under the floor caused by the blow-out. To these short joints were bolted in turn a 25-ft. standpipe, 8 in. in diameter. When all was in readiness, a rich, slow-setting, cement grout was poured into the standpipe until it appeared at the top of the pipe. In the first hole none seemed to have found its way under the floor by gravity, so a plunger, made of a length of 4-in. pipe with a piston head fitted on the lower end, was used, and with the aid of the steam hammer some 9 cu. yd. of grout was forced in. When light blows of the hammer refused to force any more grout in, the first hole was sealed, and the same process used on the remaining holes. In this way the void under the floor was thoroughly filled. The trench was refilled and the levees rebuilt and a test of 19-ft. head of water placed against the front of the gate with the water pumped down to floor level behind the gate. The test lasted for 6 hr. under full 19-ft. head, and not a leak appeared anywhere behind the gate.

Now that the repair work to the foundation has proved successful, steps are being taken to comply with the full requirements in regard to the levee surrounding the forebay and chamber, and within a month a further test of the levees will be made, namely, by raising the water 7 ft. higher, both in front of and behind each gate, than was required in the first test, and maintaining it there for six consecutive hours without excessive leakage showing. As the head will be no greater than during the first test, no fear is entertained that the gates will not stand the testing of the levee.

In discussing the method employed, one of the local engineers raised the question as to the necessity of such long sheet piling when the borings showed that the same stratification extended well beyond the upstream and downstream ends of the row of sheet piles, and there seemed to be no reason why the water could not find its way around the extremities of this row of sheet piles before it would come anywhere near diving under the foot of the piling. The writer felt that the failure had taken place immediately under the center of the flooring between the gate abutments, which was the point of least resistance, and that if the original transverse rows of Wakefield wooden sheet piling had failed with 16- and 25-ft. lengths, not to mention the 2-ft. thick solid concrete transverse core 7 ft. below the bottom of the floor, a greater depth should be reached. He felt that it was also desirable that the 18-in. stratum of mixed sand and clay should be reached, but not penetrated entirely. Hence the length of 38 ft. A shorter length of interlocking piling, not extending so far beyond the upper and lower sides of the abutments, might have been sufficient, but as there is no known definite way of determining such a fact, especially when dealing with so precarious and varying a substance as so-called quicksand, the writer allowed what he believed a factor of safety equal to that allowed in designing the strength of the materials used in the gates and the abutments.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1907, for publication in a subsequent number of the Journal.]

REINFORCED CONCRETE BUILDING CONSTRUCTION.

An Informal Discussion before the Boston Society of Civil Engineers at its Meetings held September 19 and October 5, 1906.

Mr. Chester J. Hogue. — When the writer was asked to take part in this meeting his first thought was that if he could say something to stir up the concrete experts he might himself take a very brief part and then turn the meeting to his own advantage, getting more information than he would give.

Reinforced concrete of all methods of building construction seems to be attracting the most attention just now, and the design of reinforced concrete at this time certainly furnishes the best field for discussion of any branch of structural engineering.

You are all interested in the developments of engineering knowledge, but you are not all in the fix of some of us who, regardless of what we really know or of what really is known of the design of reinforced concrete, have to assert for the peace of mind of the owners and their confidence in their own buildings that we have completely mastered the science. Among ourselves, however, we may speak a little more freely, and in a short description of a typical concrete factory building the writer will mention briefly the principal points which must be decided to determine the design, and hopes you will see fit to discuss them very freely for the benefit of us all.

Reinforced concrete factory construction, from its ease and economy of execution, rapidity of erection and "everything proofness," seems to be the most distinctive development of this form of construction. On the side of economy the company with which the writer is connected has this year, by careful laying out of the work and study of the wood forms, proven beyond a doubt that a building of this construction can be built at the same cost as one with brick outside walls and wood-framed mill construction interior, and sometimes for even less if the building is high and the loads are great. In general, economy in design lies in using slabs of 8, 10 or 12 ft. span supported by lines of beams in one direction only, these beams resting directly on columns with no girders; but when a wider spacing of columns is required economy is gained by using a slab of minimum thickness, say 3 in. if the finished floor is to

be of wood on top of the concrete, or 4 in. if the finished floor is to be of granolithic laid at the same time as and as a part of the floor, spacing the beams as closely together as this slab will require and framing the beams into the girders at the third or quarter points. In construction the great point in saving of cost is in uniformity of detail and in making the wood forms carefully at first in units and then using the units over and over again as many times as possible. As for speed, we can safely guarantee to complete a building at from eight to ten days a story, and we have this year begun and completed buildings while others of equal size were waiting for their steel frames to be fabricated and erected. Everything proof, it is shown beyond doubt that in recent fires and earthquakes buildings constructed wholly or in part of reinforced concrete gave the best account of themselves; if properly built there is nothing to rot or rust; without hollow spaces there are no retreats for dust, dirt or vermin.

One point, however, shown by a number of recent failures, sounds a note of warning quite independently of the feeling of those who have put years of study into this work, that they alone should be trusted to do it,— that unless engineers and architects are themselves experts in reinforced concrete design and construction and wish to give their work very careful supervision, they should be extremely careful that the men into whose hands they intrust the erection of their buildings should know how to design them, how to build them and should care to do them right; and both they and the owners should realize that first cost does not always mean ultimate economy.

There are two types of reinforced concrete factory construction, the one with concrete outside bearing walls with few openings; the other the skeleton type of construction, the walls being simply filling in panels built afterwards. It is the latter type in which the writer is particularly interested because it is the easier to build and the more economical, and he would call your attention to the following distinctive points. The column and pilaster footings only need go down to a solid bearing unless an excavated basement is required. Where there is a basement, light walls reinforced horizontally from column to column or vertically from the basement floor to the first floor will retain the earth, the reactions being taken by the columns or by the basement and first floor, while the walls may be reinforced to carry themselves from footing to footing, requiring no foundations of their own. Where there is no basement the outside walls

need only go far enough down to prevent frost working in under them with possibly a shallow trench filled with cinders or gravel underneath, and can be reinforced to carry themselves from pier to pier and to support the walls above. By building the footings first and carefully filling, settling and leveling the earth and laying the floor on the ground, the shores to support the false work can be cut of even length and there will be a good level surface to shore from. Columns and floors are built first as in skeleton steel construction and the outside panel walls are self-supporting but not weight-bearing and are built in between the pilasters entirely independently of the floors at a later time, furnishing a convenient method of keeping the concrete gang busy while the concrete floors are setting or the wood forms are being shifted from floor to floor, or when the weather is too wet or too cold to safely permit the laying of the more important work of the floor construction.

Going back now to the question of design, the following list notes a number of important points which must be taken up for decision in designing any reinforced concrete structure:

Footings.

1. Distribution of stresses over tension flange.
2. Proportion of diameter of rod to side of footing.
3. Shear.

Columns.

1. Rich concrete.
2. Longitudinal rods and spacing of ties.
3. Hooped columns.

Beams.

1. Economical proportion of depth to length of span.
2. Spacing of rods in stem.
3. Upper rods bent up where.
4. Length beyond edge of bearing.
5. Allowable width of and distribution of stresses over compression flange.
6. Proportion of thickness of slab to width of stem.
7. Allowable unit shear in concrete when shear is taken by steel in tension.
8. Can diagonally-bent rods, vertical stirrups and plain concrete in shear be utilized together at their working strengths to resist shear, or what combinations can be made?

9. Maximum spacing of shear stirrups.
10. Are round, square or flat stirrups best?
11. Proportion of size of stirrups to depth of beams.
12. Continuous beams.

It is on these points that the writer particularly wishes to start a discussion, and will take them up briefly as follows:

Footings. (1) The footings are reinforced for tension with rods laid in two or more directions as close to the bottom of the footing as protection from rust, etc., will allow. There is no question but that the rods directly under the pier carry their full portion of the load, although the requisite number of rods to properly reinforce the footing may be spread over an area somewhat greater than the width of the pier with a fairly even distribution of stresses over the entire number of rods, but it would seem that as the spread of the rods increases in proportion to the width of the pier above, the stress in the outer rods must decrease, and the distance of the outer rods from the edge of the pier must be limited in some way, possibly by the line of shear of plain concrete, though probably it could be somewhat greater. It seems, though, that this is an important point and that for safe practice some limit should be determined which will avoid over-stressing the rods under the center.

(2) A point of importance in the design of a footing is the proportion of the diameter of the rod used to the length of the rod itself to insure safe anchorage. In a footing rod the maximum tension is at the center, decreasing toward each end, and it may be assumed that the length of rod on one side of the center serves to anchor that part on the other, and it seems to the writer that there should be some definite limit for the proportion of the diameter of the rod to its length, depending on the allowable adhesive stress of steel and concrete. If thirty-six diameters were assumed as giving a safe anchorage to a rod, its diameter should not be greater than one seventy-second of the length of the rod, or practically the length of the side of the footing.

(3) Shear in a cantilever beam differs from that in a beam supported at the ends in that in the cantilever beam, at the point of maximum tension in the rods, there is the maximum increase in stress on the rods and the maximum shear, while in the beam supported at the ends the point of maximum tension in the rods is the point of no increase in stress on the rods and the point of zero shear; that means that in the beam supported

at the ends the maximum increase in the stress on the rods takes place at the end where there is no anchorage beyond, while in the cantilever beam the minimum increase is towards the end and so the adhesive stress on the rod from shear decreases. In a beam supported at the ends it seems to be the adhesive stress on the rods near the end which causes the beam to fail, when there is no steel shear reinforcement, at what seems to be a low-unit shear on the concrete, and it seems for that reason that it is proper to use a higher shearing value on a cantilever beam than in a beam supported at the ends, even though there be no steel shear reinforcement.

Columns. (1) In columns there are three ways of getting the requisite strength. The one which the writer's company most commonly uses — because it has so far seemed to be the handiest and cheapest — is that of a rich mix of concrete, but that is inconvenient for various reasons, as, for instance, if you carry the rich mix up to the under side of the beams and then carry the mixture of the floor and beams over the column, there is a leaner and weaker concrete from the bottom of the beam to the top of the floor slab, and it would be difficult to carry the column mixture to the top of the slab and get the beam and slab concrete laid before the column concrete had begun to set, thus not giving a good bond between the two mixtures, while by building brackets from the column to the beam or by building a capital around the top of the column the increase in the cost of the centering would make it almost as cheap to build a large column all the way down. Then there is the further point that in using two or three mixes of concrete in the same building you can never be sure of getting the right mix in the right place. It is so difficult to get work done as you want it when you are on the ground, even, that it would seem to be useless to expect it to be always done right when you are away; and you cannot be there all the time and ought not, therefore, to take any more chances than you can possibly help, but try to design everything in the simplest possible way. Then again, even if you use a pretty good unit stress on rich concrete, you will find that when you get into a very tall building, or one with very heavy loads on the floors, the size is larger than the owner will ordinarily want to allow.

(2) The next way, perhaps, of getting strength is by using compression rods. Here again are difficulties. The ends of the rods where they bear one on the other at the floor levels should have faced ends and be put into some sort of a socket or tied

together in some way, or else have sufficient lap to distribute the stresses from the upper rod to the lower through adhesion to the concrete. Longitudinal rods, if you wish to have them take the same deformation as the concrete, must be stressed in proportion to the moduli of elasticity of the two materials, and that means that the steel can be used up to hardly half of its ordinary safe working strength, which is far from economical. Then again, if the distribution of stresses at the floor levels is taken care of by faced ends or by lapping enough to transfer the stresses by adhesion, there will still be a good deal higher stresses on the column at the footing than should be allowed unless the rods are to rest on bearing plates. When plain rods are not large enough to give the additional strength required, or rods larger than it would be practical to use are necessary, structural shapes must be resorted to, but structural shapes are expensive and mean delay, they being the slow things to get out of the shops, and they are hard to frame to with concrete, as it is difficult to secure proper bearings for the ends of the beams and girders and to carry the tension rods of the beams through the column in order to get continuous ties through the building and take care of the stresses over the supports.

(3) It seems that the solution of the problem might lie in a hooped column. The writer has eagerly followed developments in that line, although they do not seem to have been carried far enough in the way of tests to know what will be the final results; that is, to know to what extent hooping may be carried and whether as the result of repeated loadings and unloadings the concrete will disintegrate and run out through the spaces between the hoops. In New York, hooped columns have been built where the concrete jackets were cast first and hooped columns built inside of them. It seems to the writer that there is a good point here and that the jackets might be reinforced to a certain extent both horizontally and vertically so that it would not matter whether the concrete inside the hooping disintegrated or not, while the jackets would act as fireproofing for the hooping. In connection with hooped columns there comes up the further questions as to what should be the maximum pitch of the hooping and whether it can be carried to an indefinite extent up to a complete inclosing steel shell or whether there is a limit to its efficiency. In any kind of a concrete column except one in which structural steel shapes carry practically all of the load, longitudinal rods should be put in to take care of flexure from eccentric loads and that sort of thing, and

these longitudinal rods should be bound around horizontally at certain intervals by steel bands of some sort; this is especially important where the rods take part of the compression stresses, in order that they may not buckle and break out of the concrete. There are two limits which the writer does not ordinarily exceed in spacing these hoops, one perhaps a little less than the diameter of the column and the other not more than eighteen to twenty times the diameter of the rods.

Beams. (1) The first point to be determined in designing a beam is the depth, and it would seem to the writer that from one tenth to one fourteenth of the length of the span is a good proportion; that is, a depth in inches equal to the span in feet is usually satisfactory both for stiffness and economy.

(2) The spacing of the rods in the stem is important for the shear on the plane above the rods, for adhesion of the concrete to the rod, for providing sufficient concrete around the rods to thoroughly inclose them, for convenience in placing the concrete between the rods, and for the security of having the rods well protected from fire. If the rods are spaced by proportioning the adhesion of the rods to the shear on the plane above, the other conditions will probably be satisfied. A spacing of two and a half to three diameters is that most commonly used for rods in the same horizontal row, while if there are two rows, one above the other, the vertical spacing is usually about two diameters, although in a number of systems the two or sometimes three rows of rods are placed in direct contact, although this does not seem to the writer to be good or safe practice. If there are two rows of rods and the upper rods are bent up at their third or quarter points, the rods in both rows may probably be spaced as if there were only one row, as the upper rods will act as the tension rods of a belly-rod truss, carrying their stresses directly to the top of the beam; but if there are two rows of straight rods it seems to the writer that the shear must cross the plane just above the rods and be distributed into the rods by adhesion of the concrete and steel and that the spacing should be twice that allowed above unless there are rigidly attached shear members to distribute the increase of stress in the rods into the concrete. For fireproofing, the rods should be spaced not less than two diameters up from the bottom and in from the side of the beam.

(3) When there are two rows of rods in a beam with the load uniformly distributed, the upper ones are usually bent up at their third to quarter point or sometimes even closer to the

bearing. It seems to the writer that there are advantages in favor of the quarter point, as then the rods are not bent up until there begins to be a material reduction in the bending moment, while they will still carry a good deal of the vertical shear. In beams with concentrated loads the upper rods would probably be bent up after passing the last concentration unless this would require them to be bent at an angle greater than 45 degrees. In some systems the rods bend up at different points when they are no longer needed at the bottom for tension, thus taking out shear for practically the full length of the beam, but from the standpoint of comparative economy it would not seem advisable to have to bend rods in so many different shapes, to say nothing of the difficulty of getting the rods properly sorted and placed. The writer is convinced that it is better to keep designs as simple as possible for both economy and convenience, in addition to being surer of having the work done properly in the field.

(4) Rods bent to the top of the beam are supposed to carry their full tension stresses quite to the edge of the bearing, and they must be anchored in some way at or beyond this point. This can be done with plates, nuts and threaded ends when there is no beam beyond, but with an adjacent beam it is advisable to have a continuous tie over the support, so rods may be threaded and connected by means of turn-buckles or by lapping the rods from one beam by those of the other thirty to forty diameters if the rods in both beams are of the same number and size, or by simply carrying the rods over each beam far enough beyond the edge of the bearing to anchor themselves in the concrete if they are not the same in both beams; in this case they should be lapped far enough in addition to their own anchorage to carry the strength of the bent-up rods of the lighter beam continuously over the supports. If the ends of the rods can be turned down this bent end will safely enable the length of the anchorage to be reduced by at least one third. If a beam is not designed for full continuity it is still fixed at the ends to a certain extent by the nature and method of placing the material, and if there is no tensile reinforcement at the top of the beam over the support the deflection due to loading will probably cause a crack at the top near the bearing and this, being at the point of greatest cross shear, should by all means be prevented and sufficient reinforcement placed there to take care at least of the negative moment due to deflection, and it is a question whether a rod bent diagonally from the bottom of

the beam to near the top at the edge of the bearing is sufficient or whether in this case cracks will still take place at some little distance out from the edge of the bearing, requiring tension rods near the top of the beam for some distance out from the edge of the bearing for their prevention.

(5) Leaving the rods now and coming to the compression flange of a T-section, the first point which must be determined is the distribution of the stresses above, vertically and horizontally. Of course we must assume that the maximum compression stress is directly over the center of the stem and it seems to the writer that there is no question but that the stresses diminish on each side of the center to limits fixed by some engineers at three to ten times the width of the stem and by others at from one quarter to one half of the length of the span, but it is a question whether this distribution is rectangular, parabolic or triangular in form. Vertically the stresses will increase from the neutral axis to the top of the slab, the stress diagram being an irregular curve which approaches a straight line at low stresses and a parabola as the stresses approach the ultimate strength of the concrete. It is necessary to assume the distribution in both directions and from this work out the allowable average stress over the compression flange, which will be a variable depending on the proportion of the thickness of the slab to the depth of the beam and the spacing of the beams in proportion to the length of the span.

(6) On the assumption that the compression stresses are distributed over a width of slab somewhat greater than the width of the stem in a T-section, there must be longitudinal shear on the vertical planes where the slab meets the concrete over the stem, and this must equal the shear on the horizontal plane between the slab and the stem except for the amount of compression taken by the portion of the slab directly over the stem. The proportion of the total longitudinal shear which comes on these two vertical planes depends on the proportion of the width of the stem to the width of the slab assumed to be in compression, but as a general rule the stem should not be more than two and one half to three times the depth of the slab; or perhaps it would be more proper to say that the thickness of the slab of a T-section at the planes over each side of the stem should not be less than from one third to two fifths of the width of the stem.

(7) In a concrete beam reinforced with straight rods at the bottom, the limit from shear is the vertical component of the

diagonal tension stresses, and Professor Talbot has shown that in such a beam the vertical shear is equal to the diagonal tension, so that the safe vertical shear should not exceed say 50 lb. per square inch in good concrete. In a T-beam with steel shear reinforcement the conditions are somewhat different, and it seems to the writer that the vertical shearing limit should be the vertical component of the diagonal compression stresses, which would allow the vertical shear to be taken at about three times the value for a beam without shear reinforcement; but it must be remembered that this shearing value must be taken as the unit shear over an area equal to the width of the stem multiplied by the distance from the center of the compression stresses to the center of the tension stresses. It may yet be shown that such distribution of the shear reinforcement; can be made that it will be a question of direct cross shear only, and it is pretty well established that the direct cross-shearing strength of concrete is somewhat more than one half its direct bearing strength.

(8) It is a question in the mind of the writer whether, in a T-beam with both diagonally-bent tension rods and vertical shear rods, the concrete and both sets of rods may be assumed to carry shear at their working strength. It would seem perfectly proper to use the shearing strength of concrete in combination with that of diagonally-bent tension rods, or of diagonally-bent tension rods in combination with vertical or diagonal shear rods, but it seems to the writer that when vertical or diagonal shear rods are used, the shearing strength of a plain concrete beam should not be allowed in addition, because by the time the shear rods are stressed up to their working strength the concrete would be stressed beyond its tensile strength and the rods would be carrying all the stresses whether they were assumed to or not.

Mr. E. P. Goodrich has recently made some tests of beams which he reinforced with vertical shear rods, but not sufficiently to carry all the shear. Tested to destruction, the vertical shear rods were pulled apart, but at a considerably higher load than they could be expected to carry by themselves, showing apparently that the concrete acted in combination with the steel even up to the ultimate strength of the steel, and it may be that by these and further tests the value of concrete and shear rods in combination may be established.

(9) Having established the size of the shear rods to be used, the spacing at the ends of the beam depends on the shear, but

when the shear has so decreased that one shear rod is sufficient, they could theoretically be placed at panel lengths apart. Mr. Goodrich, however, has made tests of beams in which, with the shear rods at panel lengths apart, there were diagonal cracks in the concrete at the failure of the beam, while with sufficient shear reinforcement at half-panel lengths the beams failed by direct cross-shear. This would indicate that with shear rods at panel lengths apart the shearing strength would be the vertical component of the diagonal compression stresses or about one third of the direct compression strength, while with shear rods at half-panel lengths the limit would be direct cross-shear or more than one half the compression strength.

(10 and 11) There are advantages and disadvantages in different kinds of shear rods. Round and square rods will hold better by adhesion in the concrete; but to hold properly, the ratio of diameter to length would have to be sufficient to anchor the rod in the concrete above the neutral axis, while a flat bar could be more depended on for a direct bearing both top and bottom.

(12) The question of continuous beams is very interesting and one which is being given more and more consideration.

Having established the fact that some reinforcement over the supports is desirable to prevent cracking near the bearings, it becomes a question as to whether the negative moment due to deflection should be determined and reinforcement be placed to care for this, or whether you should go further and design the beam for full continuity. This in T-sections requires some provision for taking the negative compression and this may be done by deepening the beam next the column in the shape of a diagonal bracket, or by connecting the tension rods by turnbuckles, or by some contrivance which would give them a direct bearing on each other, while some engineers go as far as to design with simply continuous rectangular beams.

Except in a very simple building beams are not always in a row or of the same length of span; bracketing, turn-buckles and threaded rods are expensive, and the writer hasn't found that a continuous rectangular beam is as cheap as a single T-beam because it does not utilize the compression strength of the slab as a T-beam does. So, assuming that it is safe and proper to design a single T-beam, the writer has yet to be convinced that such a beam properly reinforced for the negative moment due to deflection is not the best and most economical. It is the opinion of the writer that, when concrete buildings are

constructed according to the best method of design and not simply the cheapest, there will be rods placed at the top of beams for their entire length, as well as at the bottom, to prevent cracks from expansion and contraction and unequal settlements of the foundation and to better tie the building together.

Mr. Leonard C. Wason. — The writer has been very much surprised at the great amount of factory work that is being done at the present time in reinforced concrete. A great many inquiries in regard to such construction have been received and more than half of all his work is of this kind. The most encouraging point is that the initiative has in every case been taken by the manufacturers themselves, who have recognized the merits of concrete and desire to use it. The fact that it is being used for all sorts of mill purposes shows very clearly that it is a question of economy rather than of mere adaptability to some particular type of factory work. It is used in textile mills, where there are light loads and rapidly-moving machinery, which is the hardest type of mill construction to meet in price.

In considering the design for reinforced concrete buildings, the design of contraction joints in walls will first be taken up. In early buildings, before there was much experience, very little steel was used in walls or floors to resist contraction, and they used to crack. Therefore the practice of using contraction joints was followed. In early work, fourteen years ago, these were placed at intervals of about 25 ft. As further knowledge was gained, more steel was used and fewer joints, until at the present time there are no limits. The Harvard Stadium, which is 1 430 ft. around, was built with joints that were not expected to open, and only two have opened. A factory now building, 377 ft. long, is tied together from end to end without any joints whatever, the method being to use sufficient steel within its elastic limit to entirely exceed the ultimate tensile strength of the concrete at each section. In this way the steel prevents the concrete from cracking, but the steel has to be placed quite close to the surface to be effective. It is necessary to place it within an inch and a half of the surface to be protected, and the bars must be not more than 10 in. apart, otherwise the concrete is liable to crack.

Walls may be constructed under two general types with subdivisions in the design of each. The most economical is to build piers to support the floor, the floor between piers being sufficiently strong to support a curtain wall. This curtain wall is filled in after the piers and floors are completed, either with thin

monolithic construction or hollow blocks. This curtain wall is bonded into a groove left in the piers to receive it. The other general type which gives the most durable and substantial construction, but is somewhat more expensive, due to the cost of centering, is to build the entire wall monolithic at one operation, the wall being of uniform thickness and solid throughout, or cored to form air spaces between windows and where there are no concentrated loads. These cores can be of such size that the shell outside of core is not less than 3 in. thick. Such walls could be thoroughly tied together horizontally to prevent shrinkage, as above stated.

In the construction of separate footings, the octagonal is preferable to the square. It is very simple to design and build. To center, take four boards, nail together to form a square; nail another of the right length across each corner, and the octagon is obtained. The steel is placed in four directions. Every bar is of the same length and therefore all work with the same stress under the center of the pier. It is possible to use quite shallow piers; that is, the depth can be one third of the projection beyond the edge of the column base, but this is not always wise. A depth equal to one half the spread is a perfectly safe figure to use; that is, the depth from the bearing of the column base to the average depth of the steel is one half of the projection of the concrete beyond the edge of column base. There should be at least 3 in. of concrete below the lower layer of bars to properly embed them and protect them from corrosion. If the size of these bars exceeds 0.75 in., the amount of the concrete below should be equal to at least four diameters. Where footings are placed in wet ground, as an extra precaution it is wise to use a mixture of 1:2:4, which is in itself waterproof, although concrete is such a good protector of steel from corrosion that even in damp places if a rusty bar is thoroughly embedded, in a month it becomes bright. It is economical to use a large bearing-plate under the column, as thereby the stress of the cantilever may be reduced and a saving in cost effected which is greater than that added by the extra size of base. Directly under the column the concrete is subject to cubical pressure and can therefore be loaded to almost any amount with safety. It is necessary to consider only the compressive stress of that portion projecting beyond column base in order to resist the compression from the cantilever action. In a footing of the character here described the shear in concrete can be practically neglected because the shearing stress will always be low.

Columns may be built of concrete or of a combination of steel bars and concrete working together, or as steel column encased in cement. The use of all concrete, using a rich mixture to increase the strength, is the best method, this being the cheapest form of reinforcement possible. One part cement to one part of crushed stone with a working stress of 1 200 lb. per square inch can be used. Tests made at the Watertown Arsenal indicated that at the end of one month the ultimate compressive strength of such a mixture would be at least 5 000 lb. per square inch, and therefore 1 200 lb. would be perfectly safe. Of course using this method implies that considerable care must be exercised in mixing and placing. On large work which is being executed rapidly, without this care it might happen that the wrong mixture would be used in a column. This, of course, would be dangerous, but no practical difficulty has been experienced in changing mixtures and seeing that special batches were placed where wanted. Of course it is necessary to carry a mixture right through the thickness of a floor as well as through the column. This can be easily done by placing vertical boards in the girders and beams meeting at the column, filling the rich mixture inside and the floor mixture outside, afterward drawing out the boards while both mixtures are still wet and are filled to the same level. In columns designed for concrete to sustain the entire load, use vertical steel in the piers only as a safeguard against possible eccentric loading or flexure and to obtain a rigid joint with the floor. If rich mixtures are carried to an extreme, columns might be too small in cross section. It is unwise to make any column nine or more feet long less than 10 in. square.

When the load is divided between steel of any section and concrete, the stresses are distributed in the proportion of the moduli of elasticity of the two materials. Taking the ratio of the modulus of elasticity of steel to concrete as 10 and the working stress of concrete as 500 lb. per square inch, which corresponds to a mixture of 1 : 2 : 4, gives only 5 000 lb. per square inch as the compressive stress in the steel. With richer mixtures the ratio is less while the stress is higher, and the result is but very little different.

After concrete has set for a month it begins to shrink and continues to for about six months, when it reaches its limit. During the first month the adhesion between the concrete and the steel becomes considerable, although it does not reach its maximum strength. The above-mentioned shrinkage when the

concrete is exposed to the air on all sides amounts to 0.015625 in. to 0.03125 in. in length of 12 ft. Taking 0.024 in. as an average shrinkage, this shortening is equivalent to that produced by a stress of 500 lb. per square inch. As this exceeds the tensile stress of concrete, this latter stress, being about 300 lb. per square inch, may be taken as a force producing compression in the steel and by the reaction of the steel producing tension or reducing compression, as the case may be, in the concrete. It is on account of this reaction of the steel producing tension in the concrete that the tensile stress is used rather than the larger force which would produce a shortening equivalent to 500 lb. per square inch. This tensile stress multiplied by the ratio of the moduli of elasticity would permit an additional stress in the steel of 3 000 lb. per square inch, and when combined with the load a total stress of 8 000 lb. per square inch, and in the concrete an apparent stress of 800 lb. may be used, which in reality, however, is only the 500 first mentioned.

In the actual construction of a building the concrete has about a month to set before any considerable portion of its ultimate load is brought upon it, no matter how rapidly the structure may be erected, and as a well-designed structure should carry its maximum load when a month old, the above allowance of stresses is legitimate and safe.

The adhesive bond between steel and concrete is at least equal to the tensile stress. In some experiments it has been found to be very much greater. This is sufficient to transmit from the concrete to the steel, in the thickness of a floor, the increment of stress the steel must take through the story below. Thus the concrete is not overloaded in transmitting the stress from a floor to the steel in the column below. The bars should be faced and set on top of each other, being held in position by a sleeve. When bars are lapped, as is sometimes done, at the top of the splice, the concrete must take more than its proportion of the load coming upon the column in order to transmit to the lower bars in the length of the splice that portion which they are expected to sustain. Through the length of the splice the concrete is receiving more than its allowable working stress. This method of design is in somewhat common use, but it is not a safe method unless the concrete can carry a large part of the total load, and when it can the steel is of little value.

By increasing the size of the footing so that its cross-sectional area is more than equivalent to the area that would be required if plain concrete were used to carry the entire load of column,

and by making it deep enough to absorb by adhesion the load carried by the steel, a bearing-plate may be omitted at the bottom, but this style of footing is expensive. It is always better to use a base plate of sufficient size to distribute the load from the steel bars over the footing. It can then be made shallow, as is usual, and economy results. In the Ingals Building in Cincinnati the columns in basement were about 34 in. by 45 in. in section. Near the center were two bars 4 in. in diameter and four bars 3.3125 in. in diameter to assist in carrying the compressive load. Near each of the outer and inner faces were five 1-in. square twisted steel bars to resist possible flexure and to make a rigid bond between column and floors in order to resist flexure due to wind pressure. The load to be sustained was 1 550 000 lb. A cast-iron base-plate was used having a planed seat for each of the six large bars and enlarged to a bearing area on the footing of 4 ft. 10 in. by 4 ft. 7 in. This base-plate weighed over a ton. It is better to have a few big bars near the center than many small ones near the surface when they are designed solely to carry a compressive load.

By actual tests conducted with care at various testing laboratories it has been demonstrated that the steel does not sustain as large a load as might be expected from the above discussion. In a large enough number of cases to form an average, the columns carried but slightly more load than plain columns of the same dimensions and identical mixture. These tests indicated that the reinforced columns were not enough stronger to justify their use from an economical standpoint.

The combination of structural steel and concrete can be illustrated by describing one actual design. In a seven-story warehouse the roof and upper three stories were carried by concrete alone. In order to avoid too large a size, a structural steel column was used from this point to the ground. Two stories were carried by the steel work entirely. The two lower stories were carried entirely by the fireproofing of the steel, which in this case was made a little heavier than would be necessary for mere fireproofing purposes. Let it be emphasized that the two lower stories were entirely independent of the steel column within. This result was obtained by using countersunk head rivets to produce as smooth a surface as possible and by covering the steel with a jacket which was sufficient to prevent any bond between it and the surrounding concrete and to permit either to compress independently of the other. In construction the steel columns were first erected, the casing concrete of basement

was put on, first floor cast, the jacket continued and the second floor cast. In the third and fourth stories the covering was for fire protection exclusively and so far as the design was concerned could have been omitted until the building was nearing completion. This method reduced the amount of steel required because the two lower stories were supported independently while the concrete jacket was but little larger than would have been used any way for fire protection. A net saving thus resulted without an unreasonable size of column in the lower stories.

Hooped concrete columns are of little value and should never be relied upon in ordinary designs. In order to get the value of the hoops, the concrete must be compressed a considerable amount in order to cause a measurable lateral expansion, and when it has been thus compressed the safe working stress has been greatly exceeded, which is not a wise thing to do. Hooping should only be used as an added factor of safety to provide against occasional unusual heavy loads which last for a short time only in places where a large column cannot be used.

In regard to beams, so much has been written in the technical press that it is very little use to say more. There are, however, a few points worth considering, more particularly on the practical than on the theoretical side, because the theoretical side has been pretty well covered. From a practical point of view stirrups are quite useful. In ordinary construction work workmen sometimes fill in all the beams first and then fill in the panel cross-wise later, starting at one side and working to the other, so that by the time they have reached the end the concrete in the beam has begun to set. As the work is figured so that the panel acts in compression with the beam, there are liable to be serious results. Therefore the stirrups are very useful to bind beam and panel together. The stirrups used in American practice to a large extent are useless, because they do not extend out into the panel. They should have a projection into the panel of at least a foot. Then the beam and panel are well bonded together. Experienced designers use them partly for that purpose, especially near the center of the span. If the whole floor is cast as a unit, of course stirrups are not necessary as a tie between beam and panel, but this is not always a convenient thing to do.

Once, years ago, the writer made a very careful study of long span floor design to get the relation of spacing of beams to panels for the maximum economy, taking into consideration the

cost of materials and the cost of labor as it then existed. That study led to the selection of 3-ft. centers for the maximum economy. If the spacing is increased, weight is added to the beam and to the panel; and if it is reduced, the cost of centers is increased without a compensating saving on concrete and steel. This was the spacing which gave under those conditions the maximum of economy. This study has not been revised, but it is the writer's opinion that under present conditions, with the high price of lumber, which makes the beam floor much more expensive to center than the slab, and the higher price of carpenter labor, the spacing would be increased from 3 to about 4 ft. for maximum economy. The practical considerations of mill design often require a different spacing. For instance, concrete floors are frequently held to the old form of mill frame construction; that is, beams 8 or 10 ft. on centers and a flat slab between. This is less economical, but it is often necessary, and the difference in economy from the cheapest design is not very great.

A method of beam reinforcement which is coming into quite general use and ought to become more general, is that of knowing exactly where and how the steel is set. If it is put in loose, it is likely to be misplaced while filling in the concrete; but if rigidly made up into units and anchored at their ends to other units or the wooden form, they are held exactly where they belong until the concrete is filled in; therefore the construction really agrees with the design. The recent type of construction of bent-up bars crossing one another or fastened together over the columns has forced into use one variation in design, namely, the joints between various days' work. Years ago they used to be made directly over columns. The beams and girders which met on the column were made double and one half was cast on different days. But now there is such a network of steel there that it is almost impossible to put up wooden forms to stop off the concrete, and therefore the custom has come into use of making joints in the middle of spans. This is much easier to do from a practical standpoint, and from the theoretical standpoint does not weaken the construction in the least because the tension of the concrete is neglected in the design. Better work is obtained from ordinary laborers with joints in the center of the spans than with split beams. After the concrete is thoroughly set there will be a shrinkage which pulls it away from these joints, and if they are over a column this shrinkage has sometimes split the column. To avoid this the plan was adopted

years ago of using a steel plate, also hoops, to allow the beams to slip without splitting the column. This is now avoided by making the joints in the center of the span. However, this change requires considerable reinforcement of the top surface of panel over beams and girders at right angles to them in order to avoid tension cracks along their top surfaces. There is one point in designing that ought to be emphasized until its use is universal, namely, that all work ought to be designed on the basis of the working stress instead of the ultimate stress with a factor of safety.

Some of the types of construction discussed are claimed to be covered by patents. Some are valid, while others, doubtless, are not. The so-called continuous girder where bars bend up and run across support to unite with others from adjoining span is probably a valid patent. Many have been using it without consideration of patentees and if it is done wilfully those doing so are likely to come to grief sooner or later. Also, there are some patents on the so-called girder frame which have to be considered. But as a general thing all patents recently issued are so narrow in their claims and are so easy to avoid that the desired result can be obtained without infringing on anybody else's rights.

Concrete placed around steel reinforcement of necessity has to be mixed considerably wetter than is necessary when placed in large masses. The right amount of water for reinforced concrete is that at which the concrete just quakes when tamped or spaded. At this consistency it will flow properly around the bars. If more water is used the stone can settle through the mortar somewhat as through water; thus the concrete would become of uneven density. By laboratory tests it has been found that the concrete which just quakes differs but little from the maximum strength obtained with the best consistency in plain concrete, which is a plastic concrete that does not quake. Extremely wet concrete which flows nearly as freely as water never develops as great strength as plastic concrete.

Mr. Joseph R. Worcester. — I should like to say one or two words on the general subject of the use of reinforced concrete for mill construction. There are some difficulties about it that must necessarily be met face to face. The principal one, I think, is in the size of the columns. I think there is a general feeling among architects and owners that reinforced concrete columns ought to be built as small as steel columns, and the owners and architects have been forcing contractors to use

every possible device for reducing the size of columns, and the contractors have allowed the reduction to go further than is really safe in many instances. I think we must recognize the fact that we cannot build a reinforced concrete column as small as a steel column and that if we are going to use such a column we have got to give it more space. This does not amount to much in a low building, of course, but in a high building the loss in space amounts to a great deal.

Personally, I do not approve of either of the methods of reducing the size of columns advocated by the two previous speakers. I think the objections each has raised against the system of the other are very well taken, and I should say you cannot properly reduce the size either by enriching the mixture to the extent that Mr. Wason advocates or by using the hooping which Mr. Hogue is in favor of. I think Mr. Wason's point against hooping is exactly right. If you put your coil of wire into the form and then put in your concrete, the tendency of the concrete if anything is to shrink away from the wire. It certainly is not going to enlarge and bring the wire into tension, and in order to get the wire into effctive action some motion has to take place in the concrete within the wire. The Watertown Arsenal tests have shown that this motion is accompanied by deformation of the column, and I have understood from Mr. Howard that in his opinion the concrete is considerably disintegrated inside the hooping before the hooping has come into play. On the other hand, Mr. Hogue has said that with a rich mixture it is pretty hard to take care of the joints at the floor levels, and I believe he is right. Mr. Wason says it can be done, but I don't believe it can be done very safely. If you stop off your column under the floor girder, then the floor mixture bears directly on the rich mixture. That will overload the floor mixture, which is not so rich. If you carry the column mixture up through the floor there is danger of a crack, pretty nearly vertical, between the mixture in the beam and that in the column. There is, therefore, a point of weakness either way. So that it seems to me that we must start with the idea that we are going to have a pretty good-sized column, and unless we are going to have plenty of room for this, we must regard it as an objection to the construction.

Another point of difficulty in using concrete is the exterior of the building if it is made of this material. So far as I am aware, the last word has not been said as to the best method of finishing an outside wall of concrete. Nothing has been said

about it by the previous speakers, and I don't propose to advocate any method of treatment, because I don't know which is the best. There is a great liability to cracks in any concrete finish, and it is doubtful whether the durability of the outside finishes used thus far has been fully demonstrated. I don't say this too positively, but I think we must learn a great deal more with regard to exterior finishes.

One other objection to concrete construction is that the loads upon footings in a reinforced concrete building are heavier than in the case of wooden framing, and where the foundations are soft a good deal more expense is involved than in the case of wooden framing. This, perhaps, is not a serious point, but it has to be considered.

Now, a word as to the mill building Mr. Hogue has illustrated. It is apparently his intention to start the wall at the ground level. This does not seem safe on account of the fact that frost is liable to work in under and disturb the floor. This danger may be obviated by carrying the wall down below frost level, but it is not good practice to lay the first floor right on the fill unless it is remarkably good material, because it will settle and then you will have cracks. It is better to have some cellar with posts and to have the lowest floor self-supporting.

With regard to details, I wish Mr. Hogue had given us more information as to what he uses in his own practice. He has raised a lot of questions for others to answer, but it would have been of great advantage to us if he had given us the benefit of his own answers to these questions. Possibly we should not agree with him, but we would certainly like to know what his opinions are in regard to these matters.

His method of figuring footings may be scientifically correct, but I must plead guilty to a much simpler way of figuring these parts myself, a way which may not be correct, but if it is not I should like to be made aware of it. Where I have a square footing I take half the resistance of the earth on each set of rods. I assume that the rods in one direction take half the upward pressure and that the rods in the other direction take the other half. I assume that we have two central cross-sections at right angles to each other, each of which is virtually an inverted T. That is, in figuring this cross-section, I assume that the only value of compression we have in the concrete is the width of the top of the trapezoidal cross-section. I think that if you figure your two sets of rods in that way and take half the pressure on each, you get safe results, so far as I am aware. I think we

must always take into account the shearing force which Mr. Hogue referred to. My practice is to allow 100 lb. to the square inch on the area obtained by multiplying height by perimeter, and not to consider the diagonal tension as we would in a beam.

With regard to the spacing of rods in the stem of beams, Mr. Hogue said that horizontally he spaced them from 2.5 to 3 diameters from center to center. There is quite a difference between 2.5 and 3. I am rather in favor of 3 myself, for the reason that the shearing area above the rods in that case is about equal to the circumference of the rod, and you have about the same unit in shear which you have in adhesion, which I think is about right. There is quite a pressure brought upon engineers sometimes to allow a closer spacing, even down to 2 diameters from center to center. That seems to me a dangerous practice. As far as the spacing vertically, which Mr. Hogue referred to, goes, I can't see any great objection to the practice of the Hennebique Company of putting two rods one over the other in contact. I would like to know if this is really unsound from theoretical reasons. I haven't been able to see them myself.

So far as lapping the rods at the end is concerned, I cannot see why it is not all right to lap far enough so that the strain in one rod may be transferred to the rod in the opposite direction by adhesion, and if you consider 40 diameters of the rod sufficient to develop its strength, it seems to me that a lap of 40 diameters is sufficient to transfer the strength from one rod to another close by.

I will say one more word in answer to Mr. Hogue's questions in regard to continuous beams. There are several objections to considering beams as continuous and to methods in use for making them continuous. In the first place, if you have real continuous construction, you want to have more tensional strength at the top of the beam over the support than at the bottom of the beam at the center. That, of course, means that you have more compression at the bottom over the support than at the top at the center of the span, and where you use T-construction, as we do almost altogether, this means that you cannot use as much steel by a good deal as we like without overstraining your beam in compression. Mr. Hogue suggests that that can be relieved by the use of bracketing, but on the top of your bracket, between the bracket and the beam, you are almost sure to have a joint, because you fill up to the bottom of the beam and lay the beam afterwards, and you have a weak spot there for transference of shear into the bracket. Then, again, it seems to me that it is

not good engineering practice to assume that your beam is fixed over a support when it is only so fixed either by stiffness in the column or by the live load in the adjoining span. You have very little stiffness in the column and you can't count on the live load in the adjoining span. It seems to me that it is better practice to figure your beams as if they were supported at the ends. While I do not believe in figuring on the continuity, it is, nevertheless, necessary to reinforce to some extent at the top over the supports, and that is a thing that cannot be emphasized too much. If you allow any sort of concrete construction to go over an approximately fixed support without being reinforced at the top over the supports, you will have cracks in the surface where they will be very conspicuous. This reinforcing at the top may be thrown in as added security.

Mr. Wason referred to joints which he makes in the centers of his beams as "contraction joints." I don't see how they can be "contraction" joints where your reinforcement runs through, as they must at the bottom of the beam. They are really set joints, but I do not see how they can be contraction joints.

PROF. LEWIS J. JOHNSON. — I am not often inclined to disagree with Mr. Worcester, but I think there is something to be said on the other side of this question of continuity of reinforced concrete beams.

The question seems to be, Shall we or shall we not count on continuity in the design of slabs, beams and girders? This question proceeds upon the assumption that it is beam action and not arch action which is to exist. This assumption is almost universally adopted and is doubtless correct unless in cases where the ratio of depth to span is exceptionally great. More attention is likely to be given to this question of arch action than has been given to it in the past. But, granting beam action to be the proper basis of design, I cannot see how any one can doubt that it is continuous beam action that should be provided for. Slabs, beams and girders are continuous beams as built, and for better or for worse are going to act as continuous beams if they act as beams at all.

Objection to recognizing this fact in design seems to be based upon the supposition that designing beams as continuous would lead to mid-span sections good only for positive bending moments of about 1-40 wl^2, a figure which would be nearly correct for a load distributed uniformly over all spans at once, but would be fatally in error in the case of the far more probable instances of unequally distributed load.

Objection of a similar sort is applicable to design upon the basis of discontinuity, where ultra-cautious design for a mid-span bending moment of $\frac{wl^2}{8}$ is accompanied by a more or less complete ignoring of the negative bending moment of the supports. The assumption of simple beam action may thus prompt serious error on the side of danger quite as certainly as similarly improper application of the assumption of continuous action. That trouble from this source has not been more abundant I believe to be due partly at least to the undoubtedly considerable tensile strength of the concrete in the wings of T-section beams and girders. But if it is not safe to count on tensile strength of concrete elsewhere, it is not safe to count on it here.

The logical course to pursue is to recognize that, if the action present is beam action at all, it is continuous beam action, and to design accordingly. This means careful attention to the extreme values of the flexures at supports as well as at mid-spans due to all possible distributions of the live load. The end sections are then designed to meet these extreme conditions, and so are the mid-span sections. This is standard practice among the Germans and Swiss, and it ought to be in this country, and I believe is going to be. Of course in applying this method, as in any careful design, attention will be given to all important facts, such as stair or elevator wells interrupting the continuity in places; and in cases of doubt, assumptions unmistakably on the side of safety will, of course, be made.

The labor involved in these computations is not so great as it would seem. As a matter of fact, the extreme conditions under uniformly distributed live load will almost always be covered in case of a series of beams and slabs of equal spans by designing for a live load flexure of 1-10 wl^2 (l being measured from center to center of supports) at the faces of columns and girders, and the same amount at mid-spans; and this, too, regardless of the number of spans in the line. At the column faces flexure would be negative and at mid-spans positive, and in both cases would, of course, be combined with the dead load flexures. If the spans are short and the live loads large in comparison to the dead, top reinforcement may be required at mid-span to provide for resultant negative flexures there existent.

The similar extreme values for girders subject to concentrated loads have not been so well established, but the need of them is recognized and it is hoped that they may be forthcoming soon.

If a designer prefer, let him use 1-8 wl^2 at the mid-span section, but let him not fail to provide fully for the bending at the faces of the supports.

He must not overlook the fact that top reinforcement over supports is as logical a requirement as bottom reinforcement at mid-span.

Moreover, there is additional justification for top reinforcement in that it is of the greatest possible value in case of weakening of bottom rods by fire. The top rods through cantilever action may carry the load after the lower rods, in the far more exposed position of the two, have failed. In fact, top reinforcement does not seem to have had the attention which its merits from the fireproofing standpoint would seem to entitle it.

It may be objected that continuous beam coefficients based upon the assumption of unvarying moment of inertia may be inapplicable to reinforced concrete beams. This is certainly a fair field for research, but the practitioner may well proceed for the present with his 1-10 wl^2, taking comfort from realizing that the negative bending moment over supports would not rise above $\frac{wl^2}{8}$ even in the extreme case in which the moment of inertia becomes zero at mid-span, — the case of two abutting disconnected cantilevers, — a case most unlikely to occur. The error in the 1-10 wl^2, if any exist, must be extremely small and unimportant.

For beams under a uniformly distributed load, the top steel at the column faces and through the column may or may not be the same in amount as at mid-span, depending upon the relative depth of the beam at the two points, but I see no escape from the belief that the negative moment of resistance at the column face should be as large as the positive moment of resistance at mid-span. If, as is usual, floors are figured with T-sections, this may call for the German practice of materially deepening the stems at and for considerable distances each way from the supports, to make up for the absence of flanges on what is here the compression side of the beam.

This leads to brackets at connections of girders to columns and of beams to girders. These brackets complicate the forms and are usually unsightly. They can be obviated by making depth of stem at mid-span as great as required at the column faces, proportioning bottom steel at mid-span accordingly. This interferes with head room and adds to the quantity of concrete required. It may in some cases be practicable to diminish this depth by use of steel reinforcement in the compres-

sion lower side of the beam at the support. Though this latter reinforcement would also be effective and necessary reinforcement from the arch point of view, the brackets will in many cases be preferred to either of these alternatives.

But continuous beam action, I believe, is with us, and with us to stay; is, in fact, unavoidable. It must be reckoned with and patiently and properly provided for in all reputable reinforced concrete practice. Above all things, let us here as elsewhere adhere to the policy of preparing at all points of a structure for the most unfavorable conditions reasonably to be expected. And, finally, let us not go on imagining that we err on the side of safety when we ignore continuous beam action.

Turning now to what I came here to say, I wish to place on record some very high and perhaps unprecedented values for unit shears and unit adhesion stresses. These results were obtained in the beam tests of which I had the honor to give you some preliminary account last May. They are results obtained in the actual working conditions of a beam, and computed, as seems clearly proper, by the same methods which one should use in designing a projected beam or girder.*

* The particular methods which I have in mind have been in use in Europe and, to some extent, in this country for several years past, but as I believe they are still somewhat unfamiliar, and as they are as simple as they are logical, I will venture here to state their deduction.

Let Fig. 1, AB and CD, be two right sections of a rectangular beam with single reinforcement, the distance between them, $\triangle x$, being so short that the vertical shear, V, at one section differs only immaterially from that at the other. Call the bending moment at the two sections M_1 and M_2, respectively. Then, as is well known, $M_2 - M_1 = V \triangle x$. If b be the breadth of the beam, the maximum unit shear may be written,

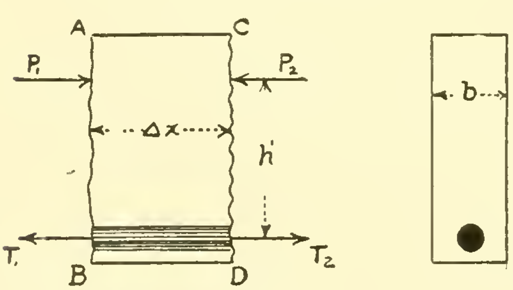


FIG. 1.

$$f_s = \frac{P_2 - P_1}{b \triangle x} = \frac{T_2 - T_1}{b \triangle x}$$

as will be realized upon observing that the total horizontal shearing tendency is the amount by which P_2 differs from P_1, which is the same as the difference between T_2 and T_1, and that the unit shear is the total horizontal shear divided by the area, $b \triangle x$, on which it is resisted.

But if h' be the distance between the centroids of tension and compression, that is, the arm common to the resisting couples composed of P_2 and T_2, and P_1 and T_1, respectively, then

These results were gained from beams 3 in. wide, 9 in. deep over all, and 8 ft. long. The steel reinforcement was 8 in. from the top of the beam, and the amount in all cases was 1 per cent. of section above the steel. The rods included smooth round, cold-twisted square and Johnson corrugated. The Johnson rods were in all cases perfectly straight, but the others were some straight and some hooked up about 3 in. at ends, and some of the smooth round rods had each end bent around a short piece of 1.125 in. rod, which thus formed a somewhat loose anchor. In no case was there an anchorage plate or washer.

$$P_1 = T_1 = \frac{M_1}{h'} \text{ and } P_2 = T_2 = \frac{M_2}{h'}, \text{ and}$$

$$P_2 - P_1 = T_2 - T_1 = \frac{M_2 - M_1}{h'} = \frac{V \triangle x}{h'}$$

Substituting this value in the expression for f_s, there follows

$$f_s = \frac{V}{bh'}$$

an expression valid, by the way, for the maximum unit horizontal shear (or vertical, of course) in any rectangular beam, whether of concrete or other material and for rectilinear or curvilinear stress distribution. The only difficulty in the application of this expression is in getting the value of h'. This value depends on the percentage of reinforcement, but for ordinary percentages and ordinary assumptions as to stress distribution in the section, h' will differ but little from 0.875 h, where h is the depth of the beam to the center of gravity of the steel. In a homogeneous beam of depth d, h' is, of course, $\frac{2}{3}d$.

Similarly, for the unit adhesion, f_a, to the steel,

$$f_a = \frac{T_2 - T_1}{U \triangle x}$$

where U is the sum of the perimeters of all the rods resisting T. $T_2 - T_1$ is the force which must be resisted by adhesion in the section and $U \triangle x$ is the surface of steel available for the purpose. Putting in the value $\frac{V \triangle x}{h'}$ for $T_2 - T_1$, as before, there follows

$$f_a = \frac{V}{Uh'}.$$

For example, if, at a section of a beam where there are three 0.5 in. round rods 8 in. below the surface, the shear is 7 000 lb., the adhesive unit stress on those rods will be, taking the closely approximate value of h' given above,

$$f_a = \frac{7\,000}{\frac{3\pi}{2} \times 0.875 \times 8} = \frac{1\,000}{4.71} = 212.3 \text{ lb. per sq. in.}$$

This deduction for f_a, it will be observed, is based upon the customary assumption of absence of tensile stresses in the concrete.

The loads were applied as shown in Fig. 2.

A slip sufficient to break an electric contact rang an alarm bell and the behavior of the rods as to slip was thus carefully watched.

Two grades of concrete were used; one was of proportions 1: 2: $2\frac{3}{8}$, the stone being scaly trap; the other, 1: $2\frac{1}{2}$: 5, the stone and sand being in this case of a character to permit a leaner

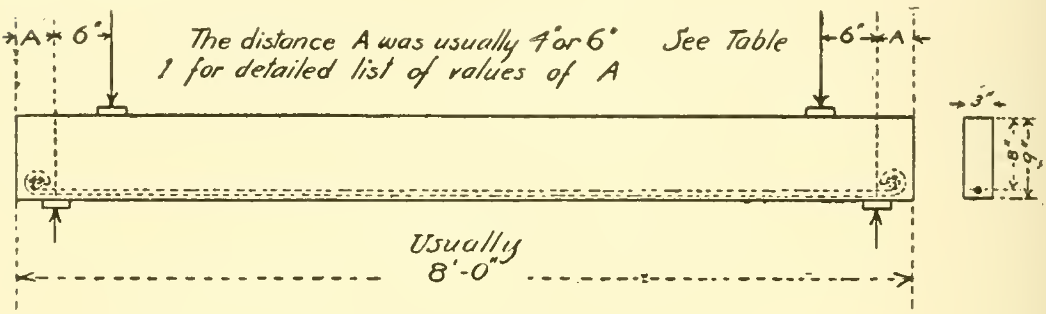


Fig. 2.

mixture. The two grades will be referred to as rich and lean respectively.

In all, twenty-five tests of this kind were made, nineteen of them on rich beams and six on lean, and as might, perhaps, be expected, failure was due *in every case* to slip of the reinforcement, regardless of the kind of rod and the conditions of the end. Consequently the actual shearing strength of the concrete was never realized, and the values given are merely the values of the shearing stress in existence at the time when the adhesion gave out. In none of these twenty-five tests were there stirrups or diagonals or other web reinforcement.

The shear thus developed averaged, in the six tests of lean beams, 470 lb. per square inch, with extremes of 573 and 233; average age, 143 days; age of extreme values, 138 days for smaller, 137 days for larger.

The shear similarly developed in the nineteen tests of rich beams averaged 628 lb. per square inch, with extremes of 750 and 488; average age, 50 days; age of 53 days for the higher value and 50 days for lower.

All of these values may, of course, be taken as horizontal or vertical shears indiscriminately. Considering that these values were in no case ultimate values, and considering that bending stresses were by no means excluded, these results add to the evidence now steadily and convincingly accumulating that the actual shearing strength of concrete has been greatly underestimated. They confirm the growing belief that failures have

been attributed to shear that were due to slip of rods or diagonal tension, phenomena closely connected with shear, but still should not be called shear.

The adhesion stresses developed in the six tests of lean beams averaged 774 lb. per square inch, with extremes of 970 and 427 lb. per square inch. The 970 figure was for a perfectly straight unmodified cold-twisted rod in a beam 137 days old. The 427 for a similarly unmodified smooth round mild steel rod, this last a figure about twice what is usually expected of such rods.

In the rich beams the average of adhesion stresses in the 19 tests was 1 094 lb. per square inch, ranging from 913 for a smooth round mild steel rod with ends hooked up, through 960 for a similar rod without the hook, to 1 367 for a similar rod bent around an 1.125-in. anchor rod as shown in Fig. 2.

The results in detail for lean and rich beams, together with the values of " A " (see Fig. 2) in each case, are as follows:

TABLE I.

Kind of Rod and Condition of End.	Lean Beams.		Rich Beams.	
	f_a lb. per sq. in.	"A" in.	f_a lb. per sq. in.	"A" in.
Rods straight and unmodified:				
Smooth round mild steel	427	4		
Smooth round mild steel			960	7
Smooth round mild steel			1 194	17
Johnson corrugated			1 182	7
Johnson corrugated			1 232	9
Cold-twisted square	853	4		
Cold-twisted square	970	4		
Cold-twisted square			1 073	7
Cold-twisted square			1 155	9
Cold-twisted square			1 161	15¾
Cold-twisted square			940	12
Rods turned up at the ends:				
Smooth round mild steel	790	4		
Smooth round mild steel			1 266	7½
Smooth round mild steel			893	6
Smooth round mild steel			913	6
Cold-twisted square	854	4		
Cold-twisted square	753	4		
Cold-twisted square			1 178	6
Cold-twisted square			1 185	6
Cold twisted square			936	4
Cold-twisted square			1 102	6
Rods turned around a 1.125 in. anchor rod (Fig. 2):				
Smooth round mild steel			918	6
Smooth round mild steel			988	6
Smooth round mild steel			1 135	5½
Smooth round mild steel			1 367	6

Hardly less striking than the high adhesion values in all these tests are their comparative uniformity regardless of differences in types of rods and end conditions, and the unimportant difference between the results for smooth and deformed rods. In fact the last beam of the series would suggest that by a very simple and natural modification smooth round rods may surpass their more pretentious and energetically advertised rivals.

But it must not be forgotten that the conditions in these tests were of an extreme nature, and the inference must by no means yet be drawn that such high results are to be expected under other conditions of loading. These peculiar conditions may include something which would render the method of computing f_a inapplicable, but it is hard to suggest just what it could be. It would seem that such abnormally favorable action as might have been present in these tests would be equally likely to be present in an actual building under similar loading conditions. Possibly a vise action as result of compression of the concrete on the under side of the beam at the support due to the very high end reactions and consequent gripping of the rods may have been in operation, but if this had been the case one would hardly suppose there would have been so great a disparity between the results for the lean and the rich mixtures. The lean would be likely to deform more and lead to a tighter grip, but yet the results do not substantiate this view at all.

More plausible is the suggestion that even with this load, unfavorable as it was for producing deflection, the beams were sufficiently bent to interfere materially with slip. This, however, is a condition of practice, and nothing to invalidate the results from a practical point of view.

It should also be stated that with other and more usual conditions of loading, slip occurred with considerably lower values of f_a than the ones above given.

Whatever the value of adhesive stress actually developed in these 19 rich beams, the fact remains that the *ultimate* strength of the 9 of them which were reinforced with smooth round rods ranged from 4.5 to 6.5 times what our customary methods of figuring and ultimate stresses would have led us to expect.

And whether the adhesion stresses as given are correct or not, the 25 beams do afford a fair basis of comparison between the two mixtures of concrete as well as of the rods and their end conditions. What I have called the lean mixture is not believed to be an uncommonly lean one from the point of view of ordinary

American practice, and that I have called rich is probably not so rich as the common European mixture as used by the best practitioners. Yet the difference between these two mixtures is striking. The rich concrete showed 42 per cent. higher average results for f_a than the lean, showed very much less variation from the mean, and furthermore were obtained at scarcely more than one third the age. It is noticeable that the disparity between the smooth round rod and its rivals is vastly greater in the case of the lean concrete than in case of the rich, as was to be expected.

If arch action was the prevailing condition, the advantage in favor of the rich mixture is not so clear as otherwise because, with the rich mixture the "A" was almost always greater than with the lean.

The nearest recorded approach to these results for f_a, so far as I am informed, are those of Kleinlogel described in *Beton u. Eisen*, 1904, page 227. His beams were of 1 : 1 : 2 mixture, reinforced with smooth round rods absolutely unmodified or bent, without stirrups or mechanical anchorage. The span was 6 ft. 7 in. and the beams were loaded at the quarter points. Size of beams was 6 by 12 in. Age not clearly stated, but was not less than five (5) months. His maximum f_a was 550 lb. per square inch (an average of a set of four beams just alike), and *was not an ultimate* value, but like the shear values above recorded merely values realized when failure occurred some other way. The percentage of steel was 0.094. In Kleinlogel's case the failure was due to stretch of the steel between the supports and subsequent crushing of the concrete. The portion of the beams outside of the loads showed no sign of failure whatever and the adhesive strength had clearly not been reached. It is easy to believe if his beams had been loaded as were the ones in Cambridge, failure by bending would have been deferred until f_a reached as large values as those I have given. His maximum value of shear, f_s, was 470 lb. per square inch, and failure in this case was attributed to diagonal tension.

Kleinlogel attributes considerable importance to the deflected condition of the beam (carrying with it, of course, a slight bend in the rods) as increasing the f_a and, very properly I think, deprecates the customary attempt to reason from results from straight pulls of imbedded rods out of blocks to the resisting power of a rod in actual service in a beam.

Professor Talbot's maximum value for unit adhesive stress upon smooth round mild steel rods in his series of 1905 was only

193 lb. per square inch, but this was not an ultimate value, for failure was to be attributed to causes other than slip. His loads were applied in a way not intended to develop extremely high values of V, while in the Cambridge beams just described of course high values of V were deliberately sought.

These very high values of adhesive stress and shear are presented for record and discussion and I cannot make it too clear that I believe the high adhesive results, at least, may be due, perhaps must be inseparably connected with, the very exceptional method of loading and should by no means be taken as a basis for design until further investigations are made. Either the results are valid as they appear, however, or there are circumstances in which the customary methods of figuring do not apply; if the latter, the reason is yet to be sought. The promising direction for the search, in my opinion, is arch action.

However all this may be, the tests certainly do encourage the hope that richer mixtures will remove much of our reasons for fear of adhesion or shear failure.

So far as verticals or other web reinforcement are concerned, there are results from other beams of that series of tests which have come to light since last spring which are worth reporting briefly at this meeting, pending more detailed publication later. They are as follows:

Some 60 to 70 of the beams of the lean mixture were loaded at the quarter points in a span of 88 in., making the space between loads 44 in. The size and amount of reinforcement the same in general as in the 25 beams loaded as in Fig. 2, except that about half of them had web reinforcement either vertical or diagonal. The vertical consisted of so-called U-bars or stirrups, and pairs of disconnected straight rods thrust into the concrete after filling the molds, the U-bars and the pairs spaced 6 in. apart measured along the beam. The diagonal consisted of Kahn bars with their wings as well as the bent-up (Hennebique fashion) portions of the main reinforcing rods, in that case smooth round rods.

The rods included round and square smooth rods of low as well as high elastic limits, Johnson corrugated, cold-twisted square, and a variety of end conditions, turned-up ends, nuts and loose washers and ends turned around anchor rods as in Fig. 2.

In the beams with vertical reinforcement the main reinforcement included all those enumerated in the preceding paragraph, but in those beams the main rods had ends with no

modification. The special anchorage of the main reinforcement was in no case combined with vertical reinforcement.

From these 60 or 70 lean beams it appeared that on the whole the best showing, so far as postponing the " first crack " (I mean visible crack) is concerned, came from beams with no web reinforcement whatever, either vertical or diagonal. The rods in some of the best of these cases had nuts and washers at the ends, and the very best had the rod ends turned around another rod as in Fig. 2. But it is not clear that end conditions were the determining influence, for smooth round rods with nuts and washers were surpassed in cases by similar rods perfectly straight and unmodified. There seemed to be no advantage in high elastic limit over low.

For ultimate strength in the same set of lean beams, the best results come with the web reinforcement, with smooth round rods with nuts and loose washers without web reinforcement a good second.

Unfortunately the rich beams loaded at the quarter points were only five in number, reinforced respectively with smooth round mild steel, smooth square mild steel, smooth square high carbon steel, Johnson corrugated and cold-twisted square, *all* (deformed rods and all) with a nut and loose washer at each end.

The twisted rod led to the highest first crack result of all, higher than the very best of the lean beam results, and all four others closely bunched alongside the best of the lean beams with the smooth round rod a little ahead of the remaining three.

The highest ultimate results from this lot of five rich beams came from the high-carbon (elastic limit, 71 200), closely followed by Johnson corrugated, next the smooth round, and the twisted square, and worst of all the square untwisted mild steel rod; all rods, be it remembered, had nuts and washers at the ends.

The two best showed much higher ultimate results than the best of the lean mixture, though the latter had web reinforcement and the former did not. The next two were about even with the very best of the lean mixture, and the worst of the five was surpassed by only few of the lean beams. The rich beams were about 103 days old and the lean 150 to 175 days old.

All this would tend to show that a rich concrete, or straight rods with nuts and washers, or both, is the most hopeful means of getting the best results both from point of view of the first crack and of the ultimate strength, and that web reinforcement, whether vertical or diagonal, is comparatively of doubtful utility from these points of view. In lean concrete the verticals at

least seem to tend to uniformity of strength, and to slower, more gradual failure.

And it should be carefully borne in mind that the washers used in those tests were the small, thin, standard washers and not secured against the nut except by the concrete as it was packed. Useful as such washers proved, they did not altogether prevent slip except with the round smooth bar, and I believe they would have shown better results still if they had been larger, thicker and secured against the outer nuts.

Richer mixtures than customary, and more carefully designed plate end-anchors and common round rods will accordingly be my next line of study.

I heartily agree with Mr. Wason's plea for uniform figuring of working loads, and I also want to urge the propriety of the general adoption in this country of the practice of the Germans in using what I haven't used until within six months myself, but I am now convinced it is best, — and that is a straight line distribution of stress with a ratio of 15. This is a practice thoroughly established in Germany and it gives, as a matter of fact, results almost absolutely identical with the parabolic distribution with a ratio of 10 such as I used to use.

Another point I have had forced on my attention lately is what we want for a factor of safety. That is a question that has not been asked to-night, but I think the factor of safety a good many times is lower than stated. It seems to me that we ought to insist on a factor of safety of 2.5 against the first crack. I think that is a good place to stop — 2.5 for the first crack and 4 or 5 for ultimate. The first crack seems to be a pretty serious matter.

Mr. Sanford E. Thompson. — One of the leading questions scheduled for discussion deals with the design of columns, and at the risk of presenting matter which is familiar to those who are constantly engaged in design, the importance of the subject leads me to include in the course of my remarks a somewhat elementary discussion for the benefit of many who have not the time to study the subject in detail.

Column Design.

It is generally accepted that some steel reinforcement shall be placed in concrete columns, but the best method is by no means settled. Many designers use very light reinforcement, such as four 0.5 in. to 0.75 in. vertical rods, with horizontal hoops spaced no greater distance apart than the width of the column, or,

on the other hand, no greater distance apart than 30 times the diameter of the hoops, the reinforcement being simply to assist in taking bending stresses and to guard against cracking. Others adopt larger vertical rods up to 4 per cent. or 5 per cent. of the area of the column, this steel being calculated to take a portion of the direct loading. Some designers employ hooping either in spiral or circular form, which is figured to take a circumferential tension produced by horizontal expansion of the concrete due to the vertical load.

A direct means of increasing the strength of the column is by using a concrete or mortar very rich in cement. Still another plan which has not been mentioned in the discussion is the selection and grading of the aggregates to produce a dense and strong concrete. Altogether too little advantage is taken in practice of this means of increasing the strength. While in many cases it is not permissible from an economical standpoint to grade the aggregate, in the construction of columns every increment which may be added to the allowable load is advantageous because allowing a proportionate reduction in the size of the column.

The use of longitudinal rods to increase the strength of the column per unit of area, and therefore to reduce its size, is not economical unless the space occupied by the columns is of considerable value, for the reason that it is usually impossible to load the steel to its full working strength. If steel imbedded in concrete could be given a working load of 16 000 lb. per square inch the cost of increasing the strength by vertical rods might not be more than the cost of increasing the area of concrete to obtain an equivalent increase in strength. For example, if a working load of 400 lb. is assumed for the concrete, the unit strength of the steel would be 40 times the unit strength of the concrete. A linear foot of steel 1 in. square at 4 cents per pound would cost 13.6 cents, while a linear foot of concrete 1 in. square, if the concrete is figured at 50 cents per cubic foot, would cost 0.35 cents, a ratio of cost of 39, or substantially the same as the ratio of strength assumed. On the other hand, as is apt to be the case in practice, if the steel, because acting with the concrete, cannot be loaded beyond 8 000 lb. per square inch, its cost for equal strength will be double that of concrete in the assumed case.

The fact should not be overlooked in discussing column loading that the preponderance of tests indicate very conclusively that longitudinal steel, if properly imbedded, does actually take a portion of the load and that it ought to be considered in

figuring the strength of the column. The reason for the low efficiency which is normally attained by the steel is not simply the difference in moduli of the two substances, but also the difference in their strength. As the column takes the load it is shortened in height, and the concrete, while more compressible than the steel, has so much lower strength that it receives its allowable load before the steel can reach its working strength. We frequently hear the assertion that the steel does not receive its full load because of its higher modulus of elasticity. This is not true. If the concrete were capable of taking as high a unit load as the steel, the steel because of its higher modulus would reach its working load first and the concrete, instead of the steel, would be insufficiently stressed. As a matter of fact, then, the reason for the low stressing of the steel is because the ratio of the strength of the steel to the strength of the concrete is greater than the ratio of their moduli. The relative loading upon the steel and the concrete at any period is theoretically in direct proportion to the ratio of their moduli of elasticity.

Since the mathematical derivation of the formulas relating to the combined action of steel and concrete in compression is seldom presented it may not be out of place to give it at this point.

Let C_1 = unit pressure upon reinforced column.

C = unit pressure upon the concrete of the column.

S' = unit pressure upon the vertical steel in the column.

$r = \dfrac{E_s}{E_c}$ = ratio of modulus of elasticity of steel to modulus of elasticity of concrete.

A = area of total cross-section of column.

A_c = area of concrete in the cross-section.

A_s = area of steel in the cross-section.

$p = \dfrac{A_s}{A}$ = ratio of cross-section of steel to total cross-section of column.

The values of C_1, C and S' may be taken either as working stresses or as ultimate stresses, although the former is preferable.

From a fundamental law in mechanics,

$$\frac{\text{stress per square inch}}{\text{modulus of elasticity}} = \text{deformation.}$$

Thus,

$$\frac{S'}{E_s} = \text{deformation in steel} \qquad (1)$$

and

$$\frac{C}{E_c} = \text{deformation in concrete.} \qquad (2)$$

Since with perfect adhesion between concrete and steel all parts of the column must undergo the same deformation,

$$\frac{S'}{E_s} = \frac{C}{E_c} \qquad (3)$$

or,

$$S' = Cr \qquad (4)$$

Formula (4) gives the relation of the unit pressure in the concrete to the unit pressure in the steel, but for practical use the total unit pressure or load in the column must be introduced.

The entire pressure in the column must be the sum of the pressure in the concrete plus the pressure in the steel; hence,

$$C_1A = CA_c + S'A_s$$

or from formula (4)

$$C_1A = CA_c + CrA_s$$

And since

$$A_c = A - A_s$$

we have

$$C_1 = C\left[\left(\frac{A - A_s}{A}\right) + r\frac{A_s}{A}\right]$$

or, since

$$p = \frac{A_s}{A}$$

we reach the result,

$$C_1 = C\,[\,(1 - p) + rp].$$

The following table is calculated from the formula with different variables:

WORKING LOADS IN CONCRETE COLUMNS REINFORCED WITH LONGITUDINAL RODS.

RATIO OF STEEL.	ALLOWABLE UNIT LOAD ON COLUMNS, C, POUNDS PER SQUARE INCH.					
p.	Ratio of Moduli, $r=10$.		Ratio of Moduli, $r=15$.		Ratio of Moduli, $r=20$.	
	C=400	C=600	C=400*	C=600	C=400	C=600
.01	436	654	456	684	476	714
.02	472	708	512	768	552	828
.03	508	762	568	852	628	942
.04	544	816	624	936	704	1 056

NOTE: C represents the allowable loading on a plain concrete column in lb. per square inch.

In selecting the modulus of elasticity for concrete to use in column design it seems to me fair (and this opinion is borne out by various tests at the Watertown Arsenal) to employ not the elastic modulus but the modulus based on the deformation before deducting the set. Strictly, the set should not be deducted from the steel either, but since the set in steel during

* This column may be used for ordinary 1 : 2 : 4 concrete.

early loading is extremely small, it may be neglected and the modulus of the steel figured in the usual way.

Tests made by Mr. Howard at the Watertown Arsenal, which are recorded in the "Tests of Materials," 1905, indicate that the formulas given above are conservative; in fact, that the actual strength of the column longitudinally reinforced is usually in excess of the theoretical strength. I have selected several of the mortar columns which give the comparative strength of plain columns and those reinforced with about 3 per cent. steel.

Actual Strength of Plain vs. Reinforced Columns from Tests at Watertown Arsenal.

Proportions.	Plain Column. Lb. per Square Inch.	Reinforced Column. Lb. per Square Inch.
1 : 2	3 700	4 200
1 : 3	2 700	3 800
1 : 4	1 600	3 400
1 : 5	1 100	2 800

For hooped reinforcement, formulas have been evolved in Europe from tests of Considère and others, and many designers in this country have adopted this method of reinforcement for the purpose of satisfying the demand for concrete columns of size approaching that of steel columns. In many cases this has resulted in the use of 1 000 lb. per square inch for unit working pressure, while in several cases which have come to my knowledge pressures in columns built of concrete in ordinary proportions with spiral hooping have run as high as 1 500 lb. per square inch. I am not ready to adopt these high unit pressures, and I believe they are unwarranted by tests thus far published either in this country or abroad.

The theory of the hooped columns assumes that the hoops or spirals confine the concrete and by preventing lateral expansion increase the load which it will bear to a degree dependent upon the area of steel in the reinforcement. Unquestionably, if concrete be confined as in a tube so as to produce what is sometimes termed "cubical compression," the load may be increased without actual failure to any limit which the tube or other surrounding medium will withstand. However, tests indicate that in practical construction, as pointed out by previous speakers, the concrete is probably overstrained before the hoops can take an appreciable load. Mr. Howard, at the Watertown Arsenal, measured the lateral expansion of a number of plain columns (that is, with no reinforcement), which are reported in "Tests of Materials," U. S. A., 1905. With concrete such as 1 : 2 : 4, the

lateral expansion under a load of 1 000 lb. per square inch was about 0.001 in. If such a column had been encased in a spiral, computations based on the deformation of the steel and of the concrete show that the maximum pull which could be attained by the steel in the spiral is about 2 500 lb. per square inch. In other words, even with an infinitesimal area of steel in the spiral, the horizontal expansion or deformation of the column due to the vertical loading of 1 000 lb. per square inch would have been only sufficient to produce a stress or pull in the hooping of about 2 500 lb. per square inch. As the area of the steel in the spiral becomes a practical quantity the stress in it becomes even less than 2 500 lb. per square inch.

The Arsenal tests further illustrate the action of the concrete by lateral measurements upon the column after excessive loading. In an experiment where the concrete column was loaded nearly to its breaking point and the load removed and then gradually replaced, the lateral expansion of the column under the same loads as before was very largely increased, the expansion under a load of 1 000 lb. per square inch being now 0.004 to 0.006 in. The elastic limit had evidently been passed in the first loading. The column which I have indicated had no hooping, but if it had been hooped it is evident that in the latter part of the test, after the concrete had been overloaded, the steel spirals would have taken a fair amount of pull. Is it conservative design, however, to permit so high pressures in the concrete itself at any period, and is it not possible, nay probable, that the concrete may be so structurally damaged that repeated loading or vibration may produce not merely cracks, but entire disintegration of the concrete within the hoops?

Undoubtedly hooping does increase the strength of the column, but unless the hoops form a continuous tube or else are near enough together to prevent the concrete from crushing out between them, it is questionable whether the use of steel in this form is really economical if the working stresses in the concrete are held within safe limits.

I had the pleasure of witnessing one or two of the tests at the Arsenal upon full-sized hooped columns. In a general way it appeared to me that the hooping increased the strength of the column so that the strength at the time of the first crack was approximately the same as the strength of a cube of similar concrete. In other words, the hooping counterbalanced the effect of the length and increased the unit strength of the column to the unit strength of a similar cube.

Pressure in Beams due to a Negative Bending Moment.

Referring for a moment to the compression in the bottom of T-beams at their supports, due to negative bending moment, it seems fair when figuring the strength of the lower portion of the beam in compression that we should take into account the compressive strength of the steel reinforcement which extends across over the column. Thus, suppose there is 2 per cent. of steel in a T-beam, — this 2 per cent. being figured upon the beam exclusive of the flange, — and suppose that half of this, or 1 per cent., is carried over the support in the lower portion of the beam, then this steel will be found by computation, using the ordinary formula for steel in compression, to be equivalent to a considerable area of concrete, and will assist in providing for the compression due to the negative bending moment.

Bending of Steel in Slabs.

The report upon a series of tests upon slabs which has recently come to my attention illustrates the advisability when shaping the steel for bent-up rods in a beam or slab to make the bends at an obtuse angle instead of at nearly a right angle, as is sometimes done. In the experiments referred to, a portion of the tests were made upon continuous slabs of three spans, fairly uniform loading being attained by four independent heaps of pig iron on each of the spans. A part of the rods in the slab were bent up about at the one-quarter or the one-third points (I am not sure which), and in nearly every case the first crack occurred at a point which approximately coincided with the point at which the bends — which were nearly right angle bends — occurred. The cracks usually started at about one half of the ultimate strength of the slab. A similar set of simple slabs reinforced with horizontal rods and supported simply at the two ends showed scarcely any crack until very near the ultimate strength of the slab, this ultimate strength being nearly the same as the ultimate strength of the continuous slab.

The cracking in the continuous slabs was probably due to the fact that as the steel in tension approached its elastic limit its area was slightly reduced by the pull, and the length of the horizontal portion of the bent-up rods was insufficient to give sufficient adhesion to the concrete, hence there was a tendency to slip, which caused the rod to partly straighten out at the bend and crack the concrete there.

Another line of discussion which it would be profitable to take up is the matter of safe working loads which it is proper to use in design.

Mr. F. H. Fay. — One thing I should like to ask Mr. Thompson and that is, in the matter of columns, whether any special provision is made to take the stress from the steel at the ends of the column? In other words, if it is not taken out, what becomes of it? Is it taken by direct bearing on metal supports at the base of the column, or what other way is it taken care of?

Mr. Thompson. — Provision should be made for transferring the stresses at the lower ends of the rods into the footing by plates or washers or some other means. This is an important point and is always considered in good design.

Mr. Fay. — That is what I was getting at. It seems to me highly important to provide some means of getting your stress properly out of the steel reinforcement into the column foundation.

Mr. William Parker.— In one case the stress referred to is taken from the column into the footing by running the bars down through the footing so that there is length of bar imbedded in the footing sufficient to transmit the stress, which the bar received from the column, into the footing concrete. From the top of column base, about at the basement floor, the vertical column bars, which in this case are corrugated, extend about 4 ft. into the mass of concrete of the column base and footing slab.

Professor Johnson. — I think that point is very important, and it is interesting, I think, to note that — certainly in some of the best-known cases of tests on longitudinal rods — no provision is made for taking care of the concentrated stress at the ends of the steel rods. I think tests under such conditions should be scrutinized very carefully before being taken seriously.

Mr. Hogue. — May I ask, in regard to carrying the rod down into the footings, were they reinforced footings?

Mr. Parker. — They were reinforced at the bottom.

Mr. Hogue. — Well, should not there be length enough between the top of the footing and the neutral axis to anchor the rod?

Mr. Parker. — There is a reinforced footing in the form of a slab and then there is a mass of concrete above the footing which is smaller than the footing but much larger than the column; that is, there is an intermediate cube and the column rests on this intermediate cube, the bars extending down through this cube, which is about 3 ft. thick, and also extending into the reinforced slab nearly to the bottom.

Mr. Hogue. — That is, a bearing larger than the column and smaller than the footing between the bottom of the column and the footing. If that column rested directly on the footing, it probably should be distributed within the compression area, should it not?

Mr. Parker. — Yes.

Mr. L. S. Cowles. — It is probably a fact that the outer columns of a building will receive their figured loads more quickly than the inner columns, owing to the fact that the inner columns have a greater amount of live load. Now, in case the outer columns have settled more than the inner columns, is the reinforced concrete structure capable of withstanding the strain resulting from this unequal settlement? I was wondering whether such unequal settlement would be a detriment to the reinforced beams and the columns on the inside; that is, if there is sufficient elasticity to prevent injury to the beams in that case.

The Chairman (Mr. Worcester.) — That is a very interesting question, and some of the engineers here who are interested in the subject ought to answer it.

Mr. Hogue. — There is one thing which I should like to say in this connection, and that is, that I think sooner or later it is going to be much more the practice for an owner to go to an engineer and have his building designed before it is figured on. And when that is done we shall be in a position to do some things that we cannot do now. As it is now, when we contractors have to make our own designs and estimate on them in competition, we can't afford to put in any more steel than enough to keep the building up. I am looking forward to the time when owners will have buildings designed first, so that we can all estimate on the same reinforcement and have plenty of it. I think if there were rods at the tops of the beams they would take care of the strains arising from unequal settlement. Perhaps some of you noticed recently a picture of a building in Tunis, I think, — a reinforced concrete factory building, six stories high and about 50 by 100 ft., the foundation of which was entirely gone under one corner and the building was toppled over to an angle of 10 degrees, and yet the structure was standing there uninjured except in the foundations, and they were going to jack it up and put a new foundation under it. It is a good example of what reinforced concrete will stand.

Mr. Parker. — I'd like to ask Mr. Hogue to tell us, in answer to the gentleman who spoke a minute ago, if his experi-

ence does not go to show that most of the buildings are designed now-a-days in the very way that he speaks of; that is, having plenty of steel in the top and bottom of the beams, and having them so that they are practically continuous beams?

Mr. Hogue. — There is almost always steel at the top of the beam over the support, and possibly for a little way out, but usually the middle half of the beam is without reinforcement at the top.

Mr. E. R. Olin. — At the last meeting, as I remember it, Mr. Hogue favored reinforcing columns by using hoops, while Mr. Wason did not believe in the use of hoops, but in the use of a richer mixture, and I think Mr. Worcester said that each had condemned the other's method in suitable terms. I wish each of those gentlemen would reply to the objections of the other to his particular style of construction of columns.

Mr. Hogue. — I am afraid the gentleman misunderstood me a little bit. What I said was that I hoped I might be able to favor a hooped column, because it seemed to give a smaller column to carry the same load than any other kind of design. I think, myself, the rich concrete column which we use in our practice has so far been the best, because we feel safest and surest of it and know the most about it. I think that when a rich concrete column gives too large an area, or on account of the difficulty of using two different mixtures in a building, the best way to increase the strength is by using compression rods, taking the bearing at the bottom with some sort of plate. But the objection I advanced to that was that there must be some way of distributing stresses from one tier of rods to the other, either by faced ends, in which case they should be put into a socket, or by a long lap to distribute the stress from one to the other, but both those methods are expensive, as is also a bearing plate at the bottom, and it seems to me that if it could be shown that the hooping of the column could be used, it would do away with a good many of those difficulties. But the question in hooped columns is whether the concrete will flow sideways without being injured or whether it will disintegrate. If we could safely design it I think there are great possibilities for the hooped column. The difficulty there, which Mr. Howard has brought out plainly, is that the richer the concrete the slower it is in stretching the steel hoop into tension, and for that reason you reach almost the ultimate strength of the concrete before that takes place. You can make concrete so rich that you can reach the ultimate strength before the hooping is much if any good.

Then there is another difficulty, whether if you use a mixture, which will expand sufficiently to stress the hooping, it will not disintegrate. For that reason I do not think that hooped columns have been carried sufficiently far in tests to justify us in using them to any extent. But I hope something may be developed in that line.

Professor Johnson. — I do not want to be understood to be expressing an unqualified approval of hooped concrete, but it might encourage those who, like myself, are hopeful on the subject, to hear that Monsieur Considère, in the last number of *Beton u. Eisen*, seems to be more enthusiastic now than ever before, and says he has a great quantity of additional data ready to publish which is much more important than anything he has done yet, and speaks of obtaining a stress of 22 400 lb. per square inch in compression on concrete. So it seems that there is something more of importance to be expected from him. So far as column reinforcement is concerned, there is a kind of column reinforcement being used now in New York which consists of structural steel-latticed angles filled entirely with concrete. There is structural steel present in sufficient quantity to support the dead load of the building, and concrete in addition to take care of what live load may come. The steel columns in the bottom story of that building consist of four 8 by 8 angles, latticed in the ordinary way, with rivet heads sticking out to insure coöperation between steel and concrete. It certainly is effective in keeping the size of the columns down.

Mr. Edward S. Larned. — I do not wish to add anything to the theoretical discussion of this subject at this time. Some important features connected with this work, however, have not been touched upon by any of the speakers, although I think you are probably all alive to them. In the course of ordinary work some of our pet ideas are very much upset.

At the September meeting of the New England Water Works Association the concrete steel standpipe of Attleboro came up for discussion. In this work a high carbon steel was used, and the standpipe was of circular construction, with diameter of 50 ft. It appears that they had much difficulty in bending the steel to the radius, and found it expedient to hold the rods together at the splice with guy clips. There was a great deal of spring in the steel, however, and it was found difficult to keep the bars in position while the concrete was being placed, and Mr. F. A. Barbour, consulting engineer, expressed the idea that in case the steel became displaced during the earlier hardening of

the concrete, it might, in reaching its final position, pull away from the concrete, leaving a void. This I have often heard suggested in connection with concrete beam and floor construction. A practice which is coming into much use to overcome the difficulty is to jar the forms with mallets while the concrete is in a semi-fluid condition. This seems to settle the steel into position quickly and at the same time secure a very good bond between the rods and the concrete. I regard it as a most excellent practice.

I am very glad to know that the importance of the question of the consistency of concrete is coming to be more generally recognized. It was only a short while ago that engineers using concrete assumed that they could not get it too wet. In some cases they made no distinction between Portland cements and natural cements, using both of the same consistency, this, in the past few years, meaning very wet.

In speaking of the consistency of concrete, engineers express their views in such indefinite terms that it is difficult to determine when a man describes a condition just what he means.

It seems to me that in making concrete for reinforced structures it should be as nearly as possible scientifically, uniformly and thoroughly prepared. We take great pains in fixing the dimensions of the gage box for sand and stone, and it seems to me that proportions of water should be as definitely fixed and kept within reasonable limits, depending on the size and character of the sand and stone aggregates.

The influence of mechanical mixing contrasted with hand mixing has a very important bearing on the consistency of the concrete and its appearance; for example, take hand-mixed concrete, where engineers require dry mixing before the introduction of water, then two, three or four turns; these turns with one gang of men mean one thing and with another gang mean something entirely different. Some men are trained to turn it vigorously, others simply roll it over, and at best the mixing is very imperfect. In mechanical mixing this variation is avoided and a more intimate and better mixture is bound to result.

In proportioning water for mechanical mixing, it is possible to use a less amount of water and yet produce a concrete of a consistency that would compare with hand-mixed concrete using a much greater amount of water. You will observe this fact if, after determining the amount of water to be used, you hold it in the mixer for a few extra turns and it appears much wetter than if you used more water and turned it out in a shorter in-

terval of time. In other words, I advocate that the mortar in concrete should be of such consistency as to readily support the aggregate and cause it to cling together, and by proper mixing with a moderate amount of water this will result in a concrete very plastic, easily flushed, productive of smooth exterior surfaces against the forms when properly handled and resulting in the densest and consequently the strongest and most water-tight concrete.

When the question of introducing concrete through intricate reinforcement becomes serious, this must be met by reducing the size of your aggregate and perhaps making it slightly wetter, but carefully avoiding the sloppy condition which one commonly notes these days.

Because of the difficulties of handling and placing stone concrete about the reinforcement of the Attleboro standpipe, Mr. Barbour has expressed the idea that had he this work to do again he might consider the use of a clear mortar without coarse aggregates, feeling that by so doing there would be less chance of voids, and it would be easier to secure water-tight work.

Professor Johnson. — I should like to call attention again to the subject of unit stresses. I wish there could be some discussion of what are fair working stresses in spread concrete footings. I should like to offer the suggestion that 100 lb. per square inch be looked upon as admissible there in what may be called punching shear, and also that 100 lb. per square inch be looked upon as satisfactory adhesion in the case of smooth, round rods in a footing. I don't know whether those figures are such as will excite comment or not, but I wish they could be discussed.

The Chairman. — Has anybody any comment to offer upon Professor Johnson's challenge?

Mr. Thompson. — The value for shear suggested by Professor Johnson, 100 lb. per square inch, is the same as mentioned by Mr. Worcester in previous discussion. I believe that this is conservative and that we may eventually reach even a higher figure for our safe unit stress for punching shear in concrete of fairly rich proportions. The experiments upon shear have given extremely varied results. In some of the tests made in Europe * very low strength has been found at first crack, even as low as 80 lb. per square inch, with an ultimate strength of, say, 360 lb. The experimenter acknowledged, however, that the strength at first crack was lowered because there was more or less transverse

* See S. Zipkes in *Cement*, March and May, 1906.

stress. This also probably affected the ultimate strength. By using reinforcement to provide for transverse stress he obtained an average of 300 lb. per square inch at first crack and 700 lb. ultimate strength. In all of these tests the proportions were 1 : 3, but the age was only 50 days. Tests at the Institute of Technology, on the other hand, where bending was eliminated, gave something like one half of the compressive strength. Tests by Feret with mortar also have shown very high shearing stresses, these being one half to two thirds the strength of similar mortar in compression.

Professor Johnson. — I don't think there is any trouble in getting compressive strength enough in the footings under any circumstances. But this question of adhesion and shear, it seems to me, is where the difficulty lies. And therefore I feel a little hesitation in following those tests reported by Professor McKibben, because the case there was so extraordinarily favorable to the development of a high shear. In actual footing we don't get conditions quite so favorable as that, even granting that the case is unusually favorable. In the case of shear, I have seen 500 to 750 lb. per square inch developed in a beam without failure due to that cause. So personally I feel safe about the 100 lb. per square inch for shear, though I hesitate to go further. As to adhesion, apparently the Germans have taken a backward step. They used to consider 100 lb. per square inch satisfactory for adhesion, but the building regulations of 1904 put it back to 63. I think the Germans went the wrong way.

If I thought 200 lb. per square inch were a proper measure of ultimate adhesion of concrete on smooth rods, I should not feel safe with 100. I should not think it anywhere near safe. I do not think the proper way to measure adhesive resistance as it occurs in beams is to take a rod and pull it out of a block by a direct pull from the testing machine. In a beam the rods are under circumstances which are totally different from those in the cases mentioned. It may not be out of place to call attention to figures I have obtained myself in beams and which I mentioned at the last meeting. I have cases here of 25 different beams in which the adhesion did not go below 500 and in one case reached 1 367 lb. per square inch, figured in the same way as one would figure adhesion in designing footings. I have 960 lb. per square inch as a result obtained with perfectly smooth, straight round rods in a very rich mixture, somewhat richer than we use in practice, but no richer than we ought to use. I have a figure of 850 and one of 970 on cold-twisted

rods. That is with a lean concrete, 1 : 2½ : 5. Those figures, running from 500 to 1 300 lb. per square inch, cannot be set aside. European results are in a similar direction, and Europeans criticise, as I think they should do, the study of adhesion by pulling rods directly out of blocks. They think the results developed in actual tests and in the testing machine should be figured by the same method. So far as the shear is concerned, in 19 cases of beams tested under my own observation there was developed in a rod from 500 to 750 — something like that — in tests involving very marked bending. It was not a case where bending had been excluded, but where distance between support and load was from 3 in. up to 6 in.

Mr. Hogue. — It seems to me that in designing a footing, which is in effect a cantilever beam, the question of direct punching shear is not as important as the average shear over the depth from the center of compression to the center of tension or the panel shear. While in a plain concrete beam — a beam supported at the ends and without vertical shear reinforcement — it has been established that we don't want to use more than 50 to 60 lb. per square inch in shear, I think that it can be greater in a cantilever beam, because there is a different relation of the increase of stress and shear in a cantilever beam from that in a beam supported at the ends. I think the adhesion in relation to shear is not as important and I think the cross-sectional shear can be taken higher than in the beam; I should say it could be taken at two to three times as much, and it seems to me that the shear on the panel from the center of compression to the center of tension and not the direct punching shear is the important point to consider.

Professor Johnson. — I should have no objection to that, I am sure. The shear, of course, reaches its maximum right near the base of the column. I have not thought very much about figuring the shear in the way Mr. Hogue suggests he would have done in these beams. But I certainly shall, after he has made that suggestion, watch both those points.

A Member. — I would like to ask, when you have a beam with two rows of rods, whether any one would defend placing the rods one above the other in actual contact, and if so, why? What reason would they give for doing it?

Professor Johnson. — I think that is very often done by people under the influence of the Hennebique Company's methods, but I think they are kept in contact only in the middle third or middle fourth of the span and then turned up.

Where they are turned up is toward the end of the span, and where they are together the demand on adhesion is moderate. It seems to me that the question in actual practice, where you find them one on top of the other, is not so important as it would seem at first glance.

The Chairman. — That is to say, you would not recommend placing them in contact where there is a necessity of developing adhesion.

Mr. J. Parker Snow (*by letter*). — The remarks by Mr. Hogue as to the desirability of basing competition bidding on designs furnished by the owners suggests the similarity of the business methods in building reinforced concrete at the present time with that of iron bridge building thirty to thirty-five years ago. At that time the builders of iron bridges made nearly all of the designs, and they pinned their faith in the efficiency of their particular design to some patented feature, either in the form of the truss or some of its component parts, rather than to the weight of metal employed. In this we see a parallelism to the many styles of deformed bars and systems of reinforcement advocated by competitive concrete workers to-day.

Patented forms of structural iron work passed off the stage years ago, and it is quite evident that reinforcing material for concrete is following the same route. Designs for steel bridge and structural work made by the owners are much more common now than in the early days, and the same will be eventually true, without doubt, of designs for reinforced concrete. In the beginning of any type of construction it is natural that owners should wish to throw the responsibility of the design, as well as the construction, on the builder.

In steel construction at the present day it is recognized as good practice to obtain bids by the pound when designs are not furnished by the owners, the sections and details to be submitted later by the builder for criticism and subsequent approval by the owner. A lump sum bid on the builder's design is considered inadvisable. This matter has been studied very thoroughly by the Committee on Iron and Steel Structures of the Railway Maintenance of Way Association, with the conclusion above.

In case of composite structures like reinforced concrete the adaptability of unit price bidding is not quite so simple as in structural steel work; but it seems that a scheme might be devised, and I suggest that the Committee on Concrete and Reinforced Concrete of the American Society of Civil Engineers

be asked to evolve a system of competitive bidding based on unit prices in the absence of designs by the owner.

Lump-sum bids on designs in competition are intrinsically bad. Unit price bidding on the same may lead to excessive sections where no expert is available for checking the designs, but the result is on the side of safety, and the excess of cost is paid by the owner as penalty for his ignorance.

At the meeting on September 26 Mr. Worcester spoke of the necessity of making concrete sills deep enough below the surface of the ground to obtain safety from frost. I have used reinforced concrete beams in a few instances as sills for brick buildings having concrete floors at the ground level without basements. The depth of sill has been a mere assumption on my part. As the buildings that I refer to are boiler houses and the like, that are warm at all times inside, I have considered 3 ft. below the ground level sufficient security against frost. At the same time I endeavored to have the back-filling under and outside of the sills done with cinders or coarse gravel as further protection.

This style of construction is quite economical in the case of brick buildings without basement, built on filled land over marshes, where timber piles are used that must be cut off several feet below the ground surface. If a continuous pile foundation is used, the strength of piling is far in excess of what is needed, and an excessive amount of masonry is required between the pile cut off and the ground line. By grouping piles in piers 16 to 20 ft. apart, and building concrete beams between them for sills on which to start the brick work, ideal conditions are obtained.

The system of construction wherein cast blocks of concrete are used for walls has not been touched upon in this discussion so far as I have observed. It seems to me that a species of this system could be used to advantage where the walls of a building are made up almost wholly of glass, as is the case with the United Shoe Machinery Company's buildings at Beverly for example. Here there are pilaster columns about 16 ft. apart, girders at each floor level and the panel wholly occupied with glass. If the girders had been cast separately beforehand and set when the columns reached the proper height, a considerable reduction in the forms could have been made and some measure of allowance for contraction obtained.

As to the proper consistency for concrete, I think Mr. Wason's claim is just right. Concrete that is wet enough so

that it can be properly mixed and made perfectly compact, that is, without air or water spaces, with reasonable labor contains water enough for complete hydration, which is all we need. By proper mixing I mean so that every side of every particle of the aggregate will be covered with the vehicle. Mr. Larned has well described the difference between good and poor mixing. The materials should be rubbed together. The hoe, if properly used, is a more efficient tool in the latter stage of mixing than the shovel. The analogy with paint mixing is quite pertinent. Most of us know the difference between paint when the dry pigment is simply stirred into the vehicle and when it is ground into the oil. In the case of concrete the aggregate represents the pigment and the vehicle is the moist cement. Citing Mr. Larned's example, a batch of machine-mixed concrete may appear somewhat dry, that is, it looks friable and brittle; with a few more turns of the machine and no addition of water it will appear much more wet. This means that the last turns have plastered all sides of every atom of aggregate with a uniform coat of moist cement. It now has a different color and sheen from what it had before; it looks pasty; it has passed a point analogous to the point of recalescence in highly heated steel; it has come to nature, as old masons say. Concrete will bear many abuses and still be good stuff, but its strength depends in some degree on proper mixing.

The proper packing of concrete has been touched upon. I believe that jarring or quaking is the most efficient. A light rammer set on the surface and rapidly pressed down and raised enough to quake the mass without raising the rammer from contact with the surface is very effective. Our member, Mr. William B. Fuller, calls this "joggling," which perhaps applies best to large masses where rubble plums are used. The object is to get all air and surplus water out of the mass, and a sharp continuous agitation is more effective than blows from a rammer.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1907, for publication in a subsequent number of the Journal.]

OBITUARY.

John Eugene Cheney.

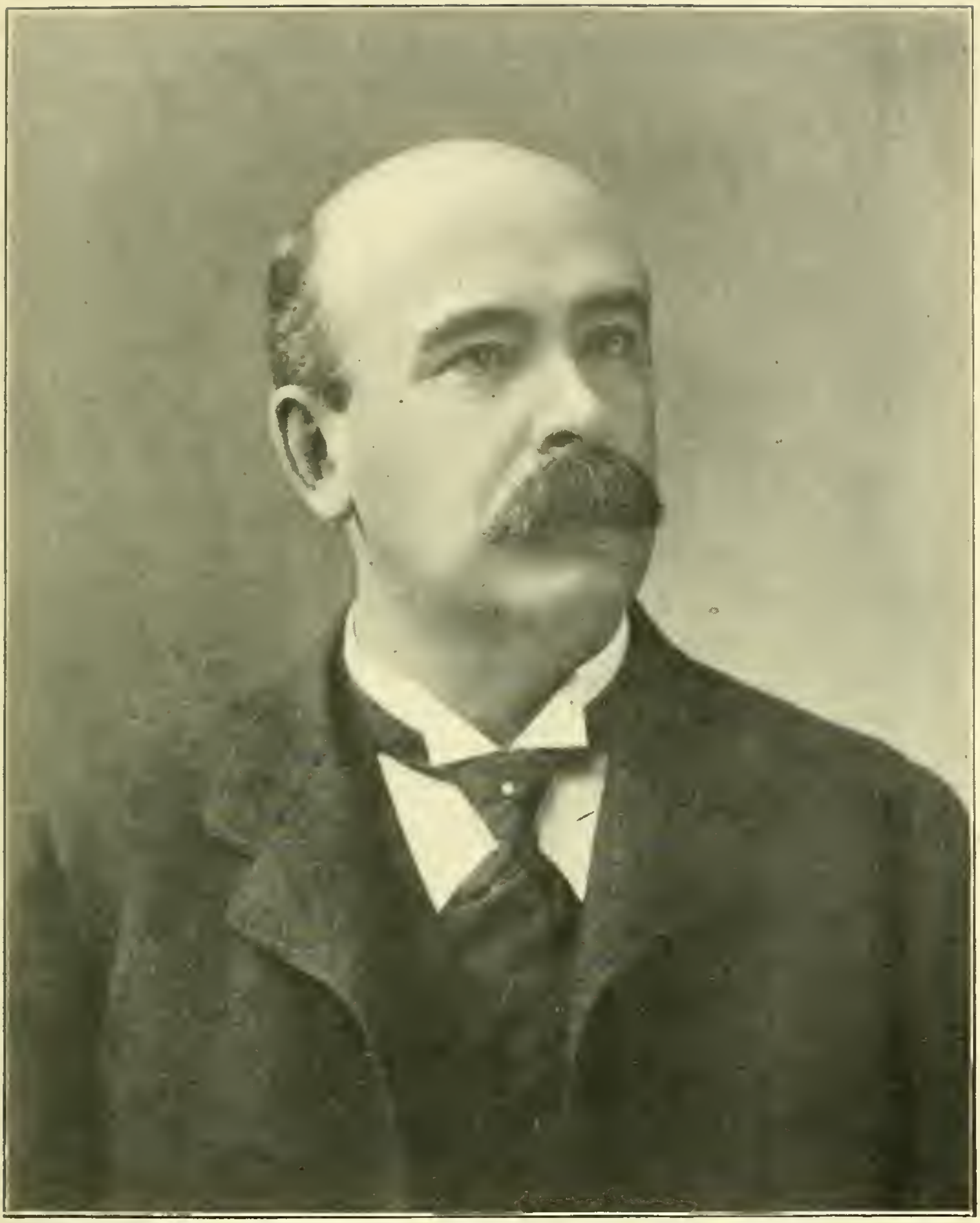
MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

JOHN EUGENE CHENEY was born in Lowell, Mass., February 12, 1847, and was the son of Cynthia Cram and John S. Cheney. His father was a direct descendant of Hannah Dustin. His parents lived originally in the town of Ware, N. H., and removed to Lowell, where for many years his father was superintendent of the Merrimack Mills, and later was engaged in the manufacture of bobbins, spools and shuttles. His father was a prominent and public-spirited citizen, active in promoting the business and educational interests of that city.

Mr. Cheney was graduated from the Lowell High School in 1865, and at once entered the Lawrence Scientific School of Harvard University. He remained there, however, for only one year. The courses at that time in this school extended through but two years, but Mr. Cheney was obliged to leave without completing his course. In recognition of the valuable professional work done by him, however, the university conferred upon him in 1900 the degree of S.B. as of the Class of 1867, and Mr. Cheney prized this degree more highly than if it had been obtained in the usual manner.

After leaving the Lawrence Scientific School Mr. Cheney worked at the Charlestown Navy Yard, and for a time with Mr. E. D. Leavitt, Jr., whose office at that time was in Lowell. In 1870 he went to Louisville, Ky., and entered the employ of the Louisville Bridge and Iron Works, where he remained for four years. Here he obtained the valuable experience which served as the foundation of his future eminence as a structural engineer. He returned to Boston in 1874 to enter the employ of the city as assistant engineer. In 1885 he was appointed assistant city engineer, which position he held until his death, acting frequently as city engineer in the latter's absence. During this period he had charge of the city bridges and he showed himself to be a very capable, conscientious and thorough structural engineer.

The work which Mr. Cheney did was of great value to the city of Boston. In his thirty-two years' service for the city



John Eugene Cheney.

nearly all the city bridges were built or renewed under his supervision, and the bridges which he constructed were well-designed, substantial structures, economically built and appropriate to their surroundings. The retractile drawbridge, a peculiar type of movable bridge possessing certain advantages for low-grade crossings, and of which many examples are to be found about Boston, was developed by Mr. Cheney from a crude and unscientific structure to one scientifically and economically designed, and remains as a distinctive feature of his work. He perfected the wooden-leaf bascule draw and was among the earliest engineers to build bascules in iron. His work in connection with drawbridge machinery and various mechanical plants gained for him a deserved reputation as a mechanical engineer. His experience upon tide-water foundations, built under the peculiar conditions to be found about Boston, was unequaled, and he was long a recognized authority upon foundation work. Among the numerous bridges which he designed and superintended, mention need only be made of the Charlestown Bridge, constructed under the direction of the Transit Commission, and containing the widest draw-span in existence. His crowning work was probably the new Cambridge Bridge, connecting Boston with Cambridge, which with its graceful arches has already taken rank as the most beautiful bridge of its kind in America.

In addition to his work for the city Mr. Cheney's abilities as a structural engineer brought him many commissions from outside parties. For a number of years he was the consulting bridge engineer of the Concord R. R., the Boston, Concord & Montreal R. R., and their successor, the Concord & Montreal R. R., and he designed most of the metal bridges on that system as well as the train-shed at Concord, N. H. He was consulting engineer also for the Connecticut River R. R. and the Massachusetts Central R. R., and in highway bridge work he was consulted by many counties, cities and towns. Indeed, the bridges which he either designed or about which he was consulted are scattered all over New England. He also did much work for architects in the construction of foundations and steel frame buildings. Among such structures in Boston are the Exchange Building, the Exchange Club, the Tremont Building, Tremont Temple, New England Conservatory of Music and the Central Building. A commendable example of mill construction which Mr. Cheney designed is the silverware factory at Concord, N. H., built by the William B. Durgin Company.

Mr. Cheney was early recognized as an engineer of unusual ability and as taking rank with the best structural engineers in this country. He was very careful in his work and took great pains to study his problems carefully, but he never was afraid to adopt a new idea or a form of construction which was novel and untried when once he had satisfied himself that it was proper. His designs were all well thought out, ingenious, economical and well adapted to the circumstances of the case.

Mr. Cheney was married in 1875 to Ellen M. Neal, daughter of the Hon. Peter M. Neal, of Lynn. After returning to Massachusetts he lived in Lynn for ten years, but later moved to Boston, and at the time of his death and for some years previous had lived in the suburb of Brighton. He died suddenly, of heart trouble, September 25, 1906. Mrs. Cheney, a son and a granddaughter survive him. The son, Herbert Neal Cheney, also a graduate of the Lawrence Scientific School, is following his father as an engineer and is at present in the employ of the Boston Consolidated Gas Company.

Mr. Cheney was a member of the Massachusetts Society and Boston Chapter of the Sons of the American Revolution and of the Society of Colonial Wars in Massachusetts. He was also a prominent member of the Boston Society of Civil Engineers and of the American Society of Civil Engineers.

Mr. Cheney was a man of great modesty of character and of a retiring disposition, but was, withal, a man of great force and determination. He was beloved and respected by all who knew him, not only for his high professional acquirements but for his lovable nature and sturdy integrity. He was a man who would never do a mean thing and he was always thoughtful of the rights of others. His memory will long be kept green in the hearts of those who knew him and his death leaves a vacancy in his professional as well as his personal circle which will not soon be filled. Men like him, so strong, so modest, so capable, so thoughtful, so kind, so helpful, are rare indeed.

George F. Swain,
E. D. Leavitt,
Frederic H. Fay,
Committee.

Association of Engineering Societies.

Vol. XXXVIII. JANUARY, 1907. No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, December 5, 1906. — The 624th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, December 5, 1906. President Layman presided. Fifteen members and one guest were present.

The minutes of the 623d meeting were read and approved and the minutes of the 414th meeting of the Executive Committee were read.

President Layman presented the report of the Executive Committee for the year just ended and showed an attendance chart of members and visitors. Upon motion this report was received and filed.

Secretary Fernald's report was then read and, upon motion, received and filed.

Treasurer Wall's report was read. Mr. Brenneke moved that the report be received and filed and the accounts audited by a special accountant at the expense of the Club. Motion seconded and carried. Librarian Fernald's report was read, received and filed.

The following committee reports were then read, received and filed:

Report of Committee on Extension of Membership. Mr. W. H. Bryan, Chairman.

Report of Committee on United States Fuel Testing Plant, Mr. Edward Flad, Chairman.

Report of Committee on Regulation of Construction of Reinforced Concrete in St. Louis, Mr. Hans C. Toensfeldt, Chairman.

The report of the Board of Managers of the Association of Engineering Societies, Mr. Hans C. Toensfeldt and Mr. A. P. Greensfelder, was read, received and filed.

Applications for membership were presented from: Harold R. Wilson, Chas. K. Traber, Maurice B. Peuguet, Frank Johnson Trelease, Oscar Guy Selden, Howard Warren Hall.

The report of the Nominating Committee for officers for the ensuing year was then read and additional nominations called for. No further nominations were made, however.

Mr. Brenneke moved that all applicants be invited to attend the next meeting of the Club at the Annual Dinner on the same basis as members of the Club. Seconded and carried.

Adjourned.

A. P. Greensfelder, *Secretary, pro tem.*

St. Louis, December 19, 1906. — (Annual Dinner, Mercantile Club.) The 625th meeting of the Engineers' Club of St. Louis was held at the Mercantile Club, Wednesday evening, December 19, 1906, at 8 P.M. Thirty-one members and eleven guests were present. President Layman presided.

After an enjoyable dinner the following toasts were responded to: W. A. Layman, "Retiring President's Address"; John A. Laird, "Gas — and More Gas"; Harry B. Hawes, "14 Feet Through the Valley"; A. S. Langsdorf, "Engineering Education"; W. S. Eames, "Skylines"; Rabbi Leon Harrison, "The Men Who Do Things"; R. S. Colnon, "Engineering Without Specifications."

Adjourned.

R. H. Fernald, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., January 14, 1907. — The twenty-fourth annual meeting of the Civil Engineers' Society of St. Paul was held at the Merchants' Hotel at 6.30 P.M.

Fourteen members and two visitors in attendance and President Claussen in the chair.

Minutes of previous meeting were read and approved.

After a few introductory remarks the President called for the annual reports of the officers of the Society, and the reports of the Secretary, Treasurer, Librarian and Auditor of 1905 accounts were read, received and ordered filed.

The Librarian was authorized to publish a classified catalogue of books and periodicals in the Society library, and Mr. J. B. Irvine volunteered to assist the Librarian in the preparation of the work.

Mr. Starkey and Mr. Heuston were appointed to audit the 1906 accounts.

The Treasurer was authorized to draw a check in favor of John W. Cramsie for care of the Society room at the Court House.

The resignation of Mr. S. B. Williamson was accepted.

The following resolutions were passed:

Resolved, That the Civil Engineers' Society of St. Paul express their gratitude by a vote of thanks to the Hon. F. C. Stevens for his gift to the Society of forty-seven volumes of Government Reports.

Resolved, That the Civil Engineers' Society of St. Paul extend their thanks to the authors, Charles B. Breed and George L. Hosmer, for the gift of their book "Principles and Practice of Surveying."

Mr. Claussen positively refusing to accept the presidency for another term, Mr. L. W. Rundlett was duly elected by ballot.

The Secretary was instructed to cast the ballot of the members present for J. Henry Fitz as Vice-President, and successively for the reëlection of the present incumbents of the remaining offices after his own reëlection in a similar way. The list of officers for the year 1907 is consequently:

President — L. W. Rundlett.

Vice-President — J. Henry Fitz.

Secretary — C. L. Annan.

Treasurer — L. P. Wolff.

Librarian — G. Z. Heuston.

Representative on the Board of Managers of the Association of Engineering Societies — A. R. Starkey.

At 7.30 the meeting was adjourned to the dining room.

After dinner the company were held closely interested until 10.30 by the responses of the following gentlemen, Mr. Claussen acting as chairman:

Mr. J. D. Du Shane spoke of the urgent necessity for the improvement of water ways.

Mr. G. O. House explained the detail of district steam heating.

Mr. Oliver Crosby told of his late trip to the Panama Canal and discussed specialized engineering.

Mr. G. W. Cooley, state engineer, gave much information in a most entertaining manner concerning good roads.

Prof. W. R. Hoag enlarged on the specialty of railroad engineering.

C. L. Annan, *Secretary.*

Montana Society of Engineers.

Butte, Mont., December 8, 1906. — The regular meeting of the Society for December was called to order by President Dunshee at 8 p.m., in the Society Room, No. 16 Leyson Block.

More than the usual number of members were present. The minutes of the last meeting were approved as read. The application for membership of Arthur Vincent Corry was read, approved and the ballots ordered mailed to voting members. Fred J. Brule was elected to membership by a unanimous vote. An exchange of courtesies in the use of library and society room, requested by the Engineering Society of Rochester, N. Y., was approved and the Secretary was instructed to reply to the request affirmatively.

The following resolutions on the death of Charles W Leimer were presented:

Whereas, In a far-away country, beneath the cliffs of the Andes, remote from countrymen, kindred and human succor, Nature, in one of her most savage moods, brought the brilliant career of Charles William Leimer to a tragic end, and

Whereas, It is but fitting that the members of this Society should express their appreciation of his brilliant career in the field of scientific endeavor, his unselfish devotion to those for whom he toiled, his unfailing success in the solution of all problems submitted to him, his achievements in foreign lands where methods were crude and materials lacking, his youthful enthusiasm wherever he toiled and triumphed, his ready response to all who sought his words of cheer and deeds of charity; therefore be it

Resolved, That this Society cherish the memory of the achievements of him who was one of its most youthful members and rejoice that it has been permitted that his reputation and career should become a part of the history of the Montana Society of Engineers. And be it

Resolved, That these resolutions be placed upon the records of this Society, and a copy of the same be sent to the family bereft.

Approved.

R. K. Humphrey,
C. W. Goodale,
C. H. Moore,
Committee.

An informal talk about plans for the approaching annual meeting was had, after which the Society adjourned.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, December 7, 1906. — Regular meeting called to order at 8.30 o'clock p.m., by Prof. C. B. Wing.

The minutes of the last regular meeting were read and approved.

The following Nominating Committee was elected by the members present to select a ticket of officers for the ensuing year: Past President Marsden Manson and Messrs. A. Ballantyne, Loren E. Hunt, Adolf Lietz and Morton L. Tower.

The Secretary was instructed to notify these members of their election.

The following papers were read and discussed:

1. " The Long Beach Hotel Accident," by Lewis A. Hicks, followed by

2. Mr. M. C. Couchot, who read some notes on the " Most Effective and Economic Methods of Reënforced Concrete Construction," and who discussed the paper just read by Mr. Hicks.

3. " The Mechanics of Reënforced Concrete," by Prof. C. B. Wing.

4. Discussion of the subject by Prof. C. Derleth, Jr., after which a general discussion took place, in which many of the members took an active part.

A paper by Mr. James C. Bennett on a similar subject was laid over to be read at the next regular meeting of the Society.

Upon motion, a vote of thanks was tendered to the authors for their valuable contributions to this branch of structural engineering, for whose wide application there appears to be an opportunity in the rehabilitation of the city of San Francisco.

Meeting adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XXXVIII. FEBRUARY, 1907. No. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, January 2, 1907. — The 626th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, January 2, 1907. President Fish presided. Twenty-nine members and twelve guests were present.

The minutes of the 624th and of the 625th meetings were read and approved. The minutes of the 415th meeting of the Executive Committee were read.

The following applications for membership in the Club were submitted:

Louis N. Beals (member), W. L. Greene (member), Wm. Arthur Ruggles (member).

The following were elected to membership in the Club: Members: August Emanuel Bjork, Daniel Breck, Maurice B. Peuguet, Francis E. Schwentler, Chas. K. Traber, Harold R. Wilson. Associate Members: Howard Warren Hall, Oscar Guy Selden. Juniors: Eugene Tritle Spencer, Frank Johnson Trelease.

A very interesting and instructive paper was presented by Mr. Carl Gaylor, entitled "Reinforced Concrete: Its Limitations." A lively discussion followed the reading of the paper, in which Messrs. H. C. Toensfeldt, von Maur, Colby, Moreno, Layman, Viterbo, Fernald, Brenneke, Bruner and Merton participated.

Adjourned.

R. H. Fernald, *Secretary*.

St. Louis, January 16, 1907. — The 627th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, January 16, 1907. Vice-President Brenneke presided. Thirty-eight members and twenty guests were present.

The minutes of the 626th meeting were read and approved and the minutes of the 415th meeting of the Executive Committee were read.

The following applications for membership were presented: Claude A. Bulkeley and Philip Florreich, Jr.

The discussion of the evening upon "Rapid Transit Facilities for St. Louis — Subway? Elevated?" was exceedingly interested and spirited.

Mr. Robert Moore, who was expected to open the discussion, was unable to be present on account of illness. The Secretary read a note from

him, which concluded as follows: " I am more than sorry not to be able to be present at the meeting, as I should like very much to hear the discussion and to add my word in favor of a subway or subways, located and, at the proper time, built with the sole view to the greatest possible public service."

Professor Van Ornum recommended three systems of surface lines, one northward along the river, one southward along the river and one westward. The question of elevated roads or subways would, in his opinion, apply only to the radial lines rather than to the north, south and west lines. As a matter of construction he regards subways as better in form than elevated roads. One of the serious questions to be considered is the arrangements of terminals and loops in the business portion of the city. One difficulty which he said had to be overcome is due to the fact that the city has permitted many building owners to extend their basements to the curb.

Mr. Albert T. Perkins, of the Terminal Railroad Commission, persented charts showing the relative number of trips made and the number of passengers carried in the city for the past eighteen years. His figures showed that the number of trips made by the transit lines is the same to-day as fifteen years ago, whereas the number of passengers carried has doubled during that period. From 60 000 000 passengers handled in 1889, he said that passenger traffic upon the street car systems of St. Louis had increased to 207 000 000 in 1906. The apparent lack of increase in the number of trips has, to some extent, been counteracted by the various consolidations from time to time, with the consequent lengthening of trips and also the increased car capacity. He emphasized the fact that the rapid increase in business in the city will necessitate increased rapid transit accommodations. He also called attention to the fact that people are moving from the more dense sections. In speaking of the relative merits of subways and elevated roads he mentioned incidentally that in Boston and New York four steps less are required to get down to the subway than up to the elevated. Subways cost four times as much as elevated roads.

Boston Subway cost \$2 500 000 per mile.
New York Subway cost \$2 150 000 per mile.
New York Elevated cost \$500 000 per mile.
New York surface lines overhead construction cost \$50 000 per mile.
New York surface lines conduit construction cost \$150 000 per mile.

Mr. Perkins stated that if subways were built he felt that they should be built by the city and then leased to the company operating the surface lines.

The charts presented by Mr. Perkins brought forth criticism from Captain Robert McCulloch, general manager of the United Railways Company, and from Mr. John I. Beggs, president of the North American Company. Both contended that there has been a great increase in the number of miles traveled per trip during the period mentioned and that the charts should have been constructed upon that basis. Captain McCulloch emphasized the fact that during the World's Fair every effort was made to run the cars for the benefit of the people and the good reputation of the city. He stated that the cars ran full in one direction but empty on the return, and that in spite of the great volume of business

the increase in operating expense, etc., was so heavy that the proposition did not pay financially.

Mr. M. L. Holman stated that St. Louis is not hampered like Boston and New York, but has the whole state west of it in which to grow. The city is rapidly growing westward and we have no right to restrict this growth by building subways, etc., in such localities that they will prohibit this natural development. At the present time we have about all the facilities that are needed. He expressed his appreciation of the fact that the cars must necessarily be more or less crowded during the rush hours, as it is impossible to pay interest on the capital invested if cars enough are used to carry everybody comfortably one way in the morning and the other way at night. He further stated that there are two natural outlets for transportation to outlying districts, one through Mill Creek Valley and the other near Portland Place and other fashionable districts in the West End, which, in spite of the present agitation, would probably have to be sacrificed finally in the interests of the problem.

Mr. H. J. Pfeifer said that if an elevated were erected he felt that the proper place for it was along the right of way of the present Suburban Road. He suggested an elevated as far east as Vandeventer or Grand Avenue and then a depression of the tracks to a subway, which probably would continue as far east as Twelfth Street or possibly Eighth, with several loops in the downtown district not on the same grade.

Mr. John I. Beggs feels that elevated roads are antique and even becoming obsolete and that a subway is the proper form for St. Louis. He pointed out the physical and financial difficulties to be overcome and that it would be practically impossible to build a subway in less than five years. If the people of St. Louis get a system of subways in ten years they may be thankful. Realizing that subways in New York cost over $2 000 000 a mile, and that the cost of such construction is increasing, he pointed out that the financing of such a proposition will take considerable time. The restrictions thrown about corporate interests by the laws of Missouri, forbidding capitalization beyond a certain figure, make the problem even more difficult. In referring again to the charts presented by Mr. Perkins, he called attention to the fact that it would be found that the total mileage had increased in proportion to the passengers carried. He stated that both the total mileage and the length of trips had been increasing. He believes that the city should construct a subway and then lease it to some company. In defending criticism of the present service on the suburban line he stated that either fifteen or seventeen more cars were running to-day on the suburban than were ever run by the Suburban Company itself, including extra trippers and all.

Mr. Wm. Bouton stated that what the people desired was the ability to get to outlying districts or to get from one part of the city to another without being obliged to go way down town and then out again. He said that the ideal condition was not to take you from where you live, down town, but to pick you up where you happen to be and put you where you want to go.

Mr. W. A. Layman pointed out that there is a close relation between the Terminal Railway situation and other transportation problems. The terminals cannot handle the freight of the city now and the city cannot spread out until the terminals can do this. He stated that the

public must decide what it wants in the way of facilities and also whether the public desires monoplies to carry out the plans.

Mr. H. L. Rohwer said that the population must increase with the business growth of the city. This means rapid transit. He believed an elevated line could be run from the Suburban right of way; but inside of the city, there is only one opinion — must have subways. How far east these should go is a question. Passenger subways should take precedence over freight.

Mr. A. P. Greensfelder suggested the passenger mile and the train mile as the proper units for laying out the charts presented by Mr. Perkins. Mr. Perkins defended the criticism of his charts on the ground that they were made from the figures that are available and that no other figures were at hand.

Mr. S. Bent Russell said that he felt that the present management of our transit lines was undoubtedly as good as that of any city in the country. He stated that he had lived in St. Louis a great many years and that the cars were no more crowded now than they used to be — because they couldn't be.

Adjourned.

R. H. Fernald, *Secretary.*

Civil Engineers' Club of Cleveland.

On the evening of January 11 the new rooms of the Club, No. 718 Caxton Building, were dedicated by a reception, attended by about 150 members of the associated clubs, and ladies. Short talks by the President, Mr. Warner, Mr. Paul, Mr. Bernard L. Green, Mr. N. P. Bowler, Mr. F. C. Osborn and others were followed by the serving of refreshments, after which the floor was cleared for dancing.

Joe. C. Beardsley, *Secretary.*

Regular Meeting at the new rooms, 718 Caxton Building, January 15, 1907, called to order by the Vice-President at 8.20 p.m. Present, 30 members and 14 visitors.

Mr. Wright, as presiding officer, very fittingly commented on the confortable amd pleasant quarters the Club has secured and highly complimented the work of Secretary Beardsley in bringing about this agreeable change.

Minutes of the preceding meeting read and approved.

Applications for active membership of Lester A. Fauver and Theodore John Tellefsen, approved by the Executive Board, were read.

The tellers, Messrs. Horner and J. E. A. Moore, reported the election to active membership of Clarence W. Courtney.

A Nominating committee, to select nominees for officers for the ensuing year, consisting of the following members, was elected: Burrows, Frazier, Herman, Honsberg, McKee, Ray and Palmer. As there were only seven nominations for this committee, on motion of Mr. Lane, seconded by Mr. Horner, the Secretary was instructed to cast the ballot for these nominees.

Mr. Harry Y. Norwood, of the Hohmann and Maurer Manufacturing Company, Rochester, N. Y., presented a very instructive and interesting

paper on "Thermometry and Temperature Regulation," illustrated by lantern slides.

Adjourned.

(Signed) David Gaehr, *Acting Secretary.*

A Semi-Monthly meeting of the Club was held on the evening of January 29, 1907, at which Mr. Walter B. Snow, of B. F. Sturtevant Company, Boston, Mass., gave an interesting account of the removal and rebuilding of their plant at Hyde Park, near Boston. The paper was illustrated with many lantern slides. There was an attendance of about 100 members and guests.

On motion of Mr. Osborn, a vote of thanks was tendered the speaker.

Joe. C. Beardsley, *Secretary.*

Montana Society of Engineers.

Twentieth Annual Meeting, January 10, 11, 12, 1907. Thursday.— The day was devoted to an inspection of the Washoe Reduction Works at Anaconda, Mont. About 25 members left Butte on the morning train, and on their arrival at Anaconda were met by several officials of the Washoe Company and escorted to the Montana Hotel, where they enjoyed the hospitality of the Anaconda Club till after lunch. A special car took the party to the smelter where, under the guidance of Messrs. Mathewson, Wraith, Whyte, Repath and Jenney a trip was made through the various departments of the plant and every opportunity was given for a thorough inspection of the same, which brought great pleasure to the visitors. Late in the afternoon a visit was made to the brick department of the A. C. M. Co., where special pains were taken to explain the workings of that concern, both as to materials and methods. Dinner at the Montana Hotel completed the labors and pleasures of the day, and during the evening the visiting members enjoyed the hospitality of the Butte members at the Silver Bow Club.

Friday.— The forenoon was made pleasant by a visit to the Montana State School of Mines. President Bowman and the faculty placed the visitors under obligations to them for the very cordial welcome extended, and the hour of departure came far too soon for the parting guests. Superintendent Wharton, of the Butte Street Railway, placed a special car at the disposal of his brother members, and early in the afternoon a trip was made to the B. & M. Co.'s plant at Meaderville. There the visitors were shown through the surface plant by Superintendent Adams and Master Mechanic Brule, and all modern improvements taken into account. A trip through the Leonard mine afforded an attractive shelter to all partakers thereof, though a fearful snowstorm raged "on top." On the way back to town a call was made at "The Street Car Barn," and many objects of interest were there seen. "A Dutch lunch" was the only entertainment of the evening.

Saturday.— The business session of the Society was called to order in Judge Lynch's court room at 10 a.m., with President Dunshee in the chair. The minutes of the last meeting were read and approved. The Secretary presented the applications for membership in the Society of Messrs.

Ring, Lindsay, McRae, Potter and Lewis, and after approval the necessary ballots were ordered to be sent out. Arthur Vincent Corry was elected to membership by a unanimous vote. The Secretary presented the ballots for the officers elect, and Tellers Whyte and Griggs counted the same and reported 43 ballots, straight. Thereupon President Dunshee declared the following officers elected for the ensuing year: President, E. C. Kinney, first vice-president, Archer E. Wheeler; second vice-president, Arthur H. Wethey; secretary and librarian, Clinton H. Moore; treasurer and member of the Board of Managers of the Association of Engineering Societies, Samuel Barker, Jr.; trustee for three years, Azelle E. Hobart. President Dunshee retiring, President-elect Kinney commenced the duties of his office by making a short speech of acceptance. The annual reports of the secretary and treasurer were then read and referred to the Trustees. The Committee on Resolutions on the death of the late Geo. H. Robinson presented the following, which were read by the secretary;

Resolutions on the Death of George H. Robinson.

Whereas, Almighty God has removed, by death, our brother member, George H. Robinson; and,

Whereas, It is fit that the members of this Society should express their appreciation of his remarkable talents and marked originality in the field of mining engineering; therefore be it

Resolved, That this Society has, in the death of George H. Robinson, lost one of its most brilliant and talented members, and that a sense of personal loss is keenly felt by every member who knew him well; and be it

Resolved, That a copy of these resolutions be spread upon the records of this Society, and a copy of same be sent to his bereaved family.

Frank L. Sizer,
William F. Word,
Albert S. Hovey,
Committee.

The resignation of Horace V. Winchell was read and the Secretary was instructed to invite him to become a corresponding member instead. Various letters of regret from absent members were read. A communication from President Bowman, of the State School of Mines, was next in order, having for its object the establishment of a Montana Geological Survey by legislative enactment. After discussion, the paper was referred to the Trustees, with instructions that they present a report on the same at the next monthly meeting of the Society. The Secretary of the Society presented the needs of a new membership list, and a compilation of the Constitution and By-Laws in a more attractive form, and after considerable discussion a resolution was adopted instructing the Secretary to publish a new list of members, with Constitution and By-Laws.

A vote of thanks was extended to all who have contributed to the success of the annual session, and the Secretary was instructed to convey the same to all parties concerned.

President Kinney called Mr. McArthur to the chair, and then made a short talk on the subject of a state irrigation law, urging the members to render their assistance in having the present bill passed, now pending in the Montana Legislature. The Secretary read the program for the afternoon and adjournment followed.

The afternoon session began at 2 P.M., President Kinney presiding. The address of the retiring President, B. H. Dunshee, was much enjoyed by all the members and an appreciative audience. Professor A. N. Winchell, of the State School of Mines, gave a very interesting account of some experiments on the genesis of copper ores, and Professor Geo. W. Craven, of the State School of Mines, presented a scholarly thesis on "Concrete" and its practical uses. A short discussion closed the exercises of the afternoon. The usual banquet completed the actual work of the annual session.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING held January 4, 1907, called to order by Vice-President Franklin Riffle. The minutes of the last regular meeting were read and approved.

The Nominating Committee appointed at the last regular meeting submitted the following selection of officers for the ensuing year:

For President — Franklin Riffle.
For Vice-President — H. D. Connick.
For Secretary — Otto von Geldern.
For Treasurer — E. T. Schild.
For Directors — Hermann Barth, Edward F. Haas, Hermann Kower, Carl Uhlig and C. B. Wing.

(Signed by the chairman of the committee), Marsden Manson.

The report was ordered received, the committee discharged and the Secretary instructed to prepare the ballots for the annual meeting.

Mr. Marsden Manson read a paper entitled "The Struggle for Water in the Great Cities of the United States," the discussion of which was postponed until the annual meeting, January 18.

The Secretary was instructed to notify the members that the paper would be brought up again on that evening.

The meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

ANNUAL MEETING, called to order January 18, 1907, at 8.30 P.M., by Vice-President Franklin Riffle.

The minutes of the last regular meeting of January 4, 1907, were read, and upon motion duly approved.

The Secretary stated that a report of the Society's work during the severe times after the catastrophe had been rendered recently and that it had been published in full in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, No. 299, September, 1906, and circulated to every member and friend of the Technical Society, to show him what had been accomplished in other lines when it was impossible to take up professional matters in the usual way. The Secretary reported that the Society had still 166 active members on its list, a copy of which he laid before the meeting.

The Treasurer thereupon submitted his report, as follows:

He stated that, owing to the loss of all the records of the Technical Society (the fire having destroyed the bank and check books of the treasurer, the receipt book and vouchers of the secretary and the memorandum book of the collector), it was not possible for him to make his account a detailed or itemized one.

Receipts and expenditures were submitted, but the balance in the hands of the Treasurer on the evening of the annual meeting, amounting to $703, must be accepted by the Society without further proof.

He submitted also a list of the standing of the members on January 1, 1907.

On motion, the report of the Treasurer was ordered received, and the balance of $703 in the treasury on January 18, 1907, approved as correct, with the instruction that the report be spread in full upon the minutes.

The tellers appointed to open and count the ballots for the annual election reported that forty-two votes had been cast and that the votes were unanimous for the following officers and directors:

President — Franklin Riffle, civil engineer.

Vice President — H. D. Connick, civil engineer.

Secretary — Otto von Geldern, civil engineer.

Treasurer — E. T. Schild, manufacturer.

Directors — Hermann Barth, architect; Edward F. Haas, civil engineer; Hermann Kower, university professor; Carl Uhlig, civil engineer; Charles B. Wing, university professor.

The chairman thereupon declared these officers duly elected to serve the Society during the coming year, and he expressed the hope that the year would be a prosperous one for all concerned.

Mr. Manson moved that the Board of Directors be authorized to ascertain in what manner a certain sum of money, not to exceed one third of the amount in the treasury, could be spent to advantage in furthering the interests of the Technical Society; that is, that it in some measure identify itself with the great work of rehabilitation of the city of San Francisco by special investigations or collection of engineering data. This motion was carried.

The paper by Mr. Marsden Manson on the "Struggle for Water in the Great Cities of the United States" was read again by the author and discussed by Mr. Luther Wagoner, Mr. Michael Casey, Mr. Hermann Barth and others.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Louisiana Engineering Society.

New Orleans, La., January 12, 1907. — Annual meeting of the Louisiana Engineering Society The meeting was called to order at 8.30 p.m. by President Hoffman, with about thirty members present.

The minutes of the previous meeting were read and approved.

The Secretary then read the Board of Direction's annual report, including the reports of the Secretary, Treasurer, Library Committee,

Auditing Committee and Outing Committee. On motion of Mr. Coleman the reports were ordered received. After discussion by various members, the following resolutions were adopted on motion of Mr. Coleman:

A resolution approving the recommendations of the Library Committee and instructing the new Board of Direction to carry them into effect; a resolution that the other recommendations of the Board of Direction be referred to the new board for study and for proper presentation to the Society.

The Chair then appointed Messrs. Theard, Duval and Zander as tellers to open and count the ballots on the vote for officers to serve during 1907. Mr. Theard, as chairman, reported that the following officers had been elected:

President — G. W. Lawes.
Vice-President — C. W. Wood.
Secretary — L. C. Datz.
Treasurer — James C. Haugh.
Member Board of Direction — John Riess.
Member Board of Association of Engineering Societies — Walter H. Hoffman.

Mr. G. W. Lawes was then escorted to the president's chair, and that gentleman in a few appropriate words thanked the members for having conferred upon him the honor of electing him to the presidency.

Mr. Walter H. Hoffman then read his annual address as retiring president. Mr. Hoffman's few words were received with applause.

President Lawes next introduced Gen. Arsene Perrilliat, who desired to say a few things in regard to the transforming of this Society into an engineer's club. General Perrilliat's idea was to the effect that the social feature should be added to the meetings of the Society and that lunches, drinks and the like should be obtainable at the rooms of the Society. His purpose is to bring the members closer together than is possible under the existing system. General Perrilliat's remarks brought about some discussion, at the end of which the following resolution was adopted on motion of General Perrilliat:

Resolved, That the President appoint three members to form a committee; said committee to meet and study a project by which this Society could be changed into an engineers' club, where the social feature will be added to the purely technical feature, and said committee to report back to the Society.

The Society then adjourned to the Old Hickory, where the annual banquet was held.

MARCEL GARSAUD, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, DECEMBER 19, 1906. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.55 o'clock P.M., President F. W. Hodgdon in the chair; sixty-nine members and visitors present.

The record of the last meeting was read and approved.

Messrs. John K. Barker, Edward Burr, Wilbur W. Davis, Burton I. Drisko, Harry W. Fitts, Edward Holmes, Elbert E. Lochridge, Thomas MacKellar, Leslie W. Millar, Thomas E. Penard, John J. Rourke and John A. Starr were elected members of the Society.

Mr. Leonard Metcalf, for the committee appointed to prepare a memoir of Freeman C. Coffin, a vice-president of the Society, presented and read its report.

On motion of Mr. W. S. Johnson it was voted to postpone indefinitely the election of a vice-president to fill the vacancy caused by the death of Freeman C. Coffin.

The President brought to the attention of members the desirability of addressing an appeal to the Massachusetts delegation in the national House of Representatives, urging them to petition the Speaker, without delay, that the bill now pending which provides for the establishment of the Southern Appalachian and White Mountain Forest Reserves, may be taken up for final action and passed at an early day in the present session. After a short discussion it was voted to refer the matter to the Board of Government, with the suggestion that a delegation be selected to write to the members of Congress from this state urging the early consideration of the bill.

Mr. Paul Winsor, chief engineer of motive power and rolling stock, Boston Elevated Railway Company, was then introduced and gave a very interesting talk on "Gas Engines and Producer Plants as Used by the Boston Elevated Railway Company."

A discussion followed, which was participated in by Mr. E. L. Clark, of the Westinghouse Machine Company; Mr. H. W. True, of the Barbour-Stockwell Company; Mr. J. C. Riley, of the Massachusetts Institute of Technology, and others.

After passing a vote of thanks to Mr. Winsor for his interesting talk, the Society adjourned.

S. E. Tinkham, *Secretary.*

Boston, January 23, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President F. W. Hodgdon in the chair; fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Benjamin Fox, George F. Hooker and Leonard C. Robinson were elected members of the Society.

On motion duly seconded the President was requested to appoint a committee of three to report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President appointed as this committee Messrs. C. F. Allen, H. B. Wood and N. S. Brock. Later in the evening this committee reported the following names as members of the Nominating Committee, and they were unanimously elected: Messrs. Frederick Brooks, Ira N. Hollis, George A. Carpenter, Frederick H. Fay and Charles B. Breed.

On motion of Mr. Adams the usual committee (Mr. Henry Manley) was appointed to make arrangements for the annual dinner.

Prof. Dwight Porter offered the following resolution, and it was unanimously adopted:

It having come to the attention of the Boston Society of Civil Engineers that during the last session of Congress a reduction of $50 000 was made in the appropriation in the Sundry Civil Bill for the work of the United States Geological Survey in gaging the streams and otherwise investigating the water resources of the United States, the Society views with apprehension this reduction in the appropriation for a work which it believes to be of great importance in the material development of the country.

Realizing that it is impracticable under state or private organization alone to carry on work of the scope that is necessary, it believes it to be for the best interest of all that the investigations should be made under national supervision.

The water resources of New England are of the utmost importance to her industrial welfare, and the present reduction in the appropriation for measuring those resources is believed to threaten the continuity of records upon which the economic development of the streams must depend.

It is, therefore, the sense of the Society that immediate restoration of the appropriation should be made to its recent amount, and that consideration should be given by Congress to the necessity of increasing the amount still further in the near future; and it is hereby resolved that the Board of Government of the Society be directed to forward copies of this resolution to each member of Congress from New England.

In the absence of the author, Mr. H. K. Higgins, the Secretary read a paper entitled "Replacement of Bridges and Allied Structures." The Secretary also read discussions prepared by Messrs. J. P. Snow and J. R. Worcester.

The discussion was continued by Messrs. Swain, McKibben, Guppy, Fay, Cowles, Manley and others.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

Boston, January 9, 1907. — A special meeting of the Sanitary Section was held at the Copley Square Hotel, forty-three members and guests being present.

Mr. L. D. Thorp, for the committee appointed at the last meeting to prepare a memorial to the late Freeman C. Coffin, reported progress.

The following resolutions were adopted by the Section:

Whereas, Death has removed our late chairman, Freeman C. Coffin, and we, the members of the Sanitary Section of the Boston Society of Civil Engineers, do sincerely mourn our loss; and

Whereas, He was not only our leader, but chief among us in service and devotion; and

Whereas, To him was due not only the conception of the idea which was the basis for the organization of this Sanitary Section, but also much of the energy which brought it into being,

Be it Resolved, That we, the members of the Sanitary Section of the Boston Society of Civil Engineers, hereby express our sense of loss and our love for our friend and colleague;

Be it Resolved, That we do hereby express our sympathy for the family of our late chairman;

Be it Resolved, That these resolutions be spread upon the records of the Society, and that a copy be sent to the wife and family of the deceased.

Mr. J. C. Chase, for the committee appointed to bring in a nomination for chairman for the unexpired term, reported the name of Leonard Metcalf, and the Secretary was instructed to cast one ballot for Mr. Metcalf.

Mr. M. N. Baker, special agent for the United States Census Bureau, made a few remarks in regard to the schedule for uniform sewerage statistics recently adopted by the Section, urging the general use of this schedule by those having charge of sewerage systems. Mr. Baker stated that the Census Bureau is now publishing municipal statistics from time to time under the heading "Social Statistics of Cities." The Bureau has decided to collect statistics in regard to sewerage and sewage disposal, and there is a prospect that at some time in the near future the agents will be sent into the field and a strenuous attempt made to collect such statistics. To a certain extent, the future action of the Bureau in this respect will be dependent upon the success of the efforts which are now being made by the Sanitary Section. If there is reasonable promise that the statistics exist and can be gathered together, and that the engineers and superintendents in charge will coöperate in the matter, there is little doubt that the Bureau will adopt the schedule prepared by the Section, or a somewhat similar one.

The subject for discussion at the meeting was "The Use of Small Pumping Plants in Connection with Sewerage Systems." The discussion was opened by I. T. Farnham, L. D. Thorp and F. A. Barbour, and was participated in by C. O. Rogers, F. I. Hayes, Bertram Brewer, A. J. Gavett and others.

WILLIAM S. JOHNSON, *Clerk.*

Association of Engineering Societies.

Vol. XXXVIII. **MARCH, 1907.** No. 3.

Engineers' Club of St. Louis.

St. Louis, February 6, 1907. — The 628th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, February 6, 1907. Vice-president Brenneke presided. Thirty-three members and eighteen visitors were present.

The minutes of the 627th meeting were read and approved.

Applications for membership were presented by Stephen Roy Culbertson (member), Charles Hamilton Fake (member), Walter Robbins (member), Lealon B. Wright (associate member).

The following were elected to membership in the Club: Louis N. Beals, Jr. (member), Claude A. Bulkeley (member), Philip Florreich, Jr. (member), Weeden L. Greene (member), William Arthur Ruggles (member).

The Secretary then reported that Mr. Seth Doan Merton had been transferred at his request from member to associate member.

The subject of the evening was "The New School Buildings of St. Louis."

Mr. Wm. B. Ittner, commissioner of school buildings for St. Louis, reviewed the work of the building department for the past ten years, describing the prevailing type of building in vogue at that time, giving the reasons for the adoption of the present prevailing plan. He stated that the old type of building cost 12 cents per cu. ft. The ventilation in the old buildings was poor. In departing from the old style questions of proper ventilation, lighting, etc., were given serious consideration, as well as other comforts for the pupils. It was decided that to be well lighted a room must be less than 28 ft. wide. A width of 25 ft. was therefore adopted, but in the last few years this has been reduced to 24 ft., with a corresponding length of 32 ft. for each room. Such a room seats 56 pupils. The buildings are not only constructed of excellent material, but a certain amount of attention is given to ornamentation and good taste in design. The buildings are so constructed that sunshine penetrates every part of the building some time during the day. The excellence of construction is shown by the fact that one building which has been up three years has not cost 5 cents for repairs.

The cost of this new type of building is about as follows: Ten years ago one building was put up for 11 cents per cu. ft., one at 12 cents and one at 13 cents. There has been a steady advance in the cost of material and labor, until to-day the cost of such buildings is about 18 cents per

cu. ft. Teachers' College cost 17 cents per cu. ft, and the Clay School, 17.7 cents per cu. ft. This cost of about 18 cents includes all painting, fencing the yard, etc., and everything inside ready for the furniture.

Mr. H. C. Toensfeldt, structural engineer for the department, described the details of construction, dwelling particularly upon the reinforced concrete work.

Mr. C. A. Bulkeley, chief engineer for the department, described at length the heating and ventilating systems. He stated that the allowance was 30 cu. ft. of air per pupil per minute and 50 cu. ft. per minute for adults. Eight changes of air are counted upon per hour in each room. He described the methods of air washing and the general question of humidity. Taking average results from nine schools for four seasons, he stated that the cost of heating and ventilating was 64 cents per 1 000 cu. ft. of space on the basis of 8 hr. per day, 5 days per week.

Mr. Robert Moore expressed the great satisfaction the School Board has felt in the work of the Department of Building. He further stated that the buildings are as fine as in any city of the country, and that they have been secured at as low a cost as any buildings of the same quality.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, February 20, 1907. — The 629th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, February 20, 1907. President Fish presided. Forty members and sixteen guests were present.

The minutes of the 628th meeting were read and approved. The minutes of the 417th meeting of the Executive Committee were read.

The following were elected to membership in the Club: Stephen Roy Culbertson, member; Charles Hamilton Fake, member; Walter Robbins, member; Lealon B. Wright, associate member.

The Secretary read two letters relating to positions available and men available for positions.

Col. J. A. Ockerson presented a most interesting illustrated paper upon the Salton Sea. He outlined in detail the many difficulties that had arisen in controlling the waters of this section and the methods adopted in damming and directing the flow of the Colorado River. The discussion by Messrs. Philip N. Moore, Bryan, Merton, Flad, Perkins and Ockerson brought out the essential engineering features connected with this proposition, as well as the relations between certain private corporations, the people of the district, the Southern Pacific Railroad and the government.

Adjourned.

R. H. Fernald, *Secretary.*

Civil Engineers' Club of Cleveland.

Regular meeting, February 12, 1907, at the Club rooms, called to order by the President, at 8.15 p.m. Present, forty-four members and five visitors.

Minutes of the preceding meeting read and approved.

The application of Sam. W. Emerson for active membership, approved by the Executive Board, was read. The tellers, Messrs. Colegrove and Clifford, reported the election to active membership of Messrs. Lester A. Fauver and Theodore J. Tellefsen.

The Secretary made a brief verbal report of the work of the House Committee, showing that approximately $435 had been spent, to date, on moving to new rooms and furnishing them.

The Nominating Committee reported the following nominations for officers for the ensuing year:

President — Mr. Charles H. Wright.

Vice-President — Mr. Willard B. Beahan.

Secretary — Mr. Joseph C. Beardsley.

Treasurer — Mr. Walter M. Allen.

Librarian — Mr. Joseph R. Poe.

Directors — Mr. George T. Nelles and Mr. Andrew B. Lea.

On motion of Mr. Hawkins, the report was accepted.

It was reported from the Executive Board, that it had been decided to hold the annual meeting at Case School of Applied Science, on the invitation of President Miller.

On motion of Mr. Herman, seconded by Mr. Ritchie, the Executive Board was directed to investigate and report on the feasibility of extending our library facilities.

On motion of Mr. Frazier, the President was requested to appoint a committee to provide for an annual banquet. The President later made the following appointments for this committee: Benjamin, W. M. Allen, Watson, Hopkinson and Carroll.

Mr. Ritchie then read a paper descriptive of the construction of the new 700-ft. dry dock of the American Ship Building Company at Lorain, Ohio, which was discussed by Messrs. Nelles, Hoffmann, Dalgleish, Herman, Hanlon McKee and others.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Boston Society of Civil Engineers.

Boston, February 20, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock p.m. Eighty-eight members and visitors present.

In the absence of the president and the vice-president, Mr. Frederic P. Stearns was elected chairman of the meeting.

The record of the last meeting was read and approved.

Messrs. Theodore W. Norcross and Robert L. Read were elected members of the Society.

On motion of Mr. Street, the thanks of the Society were voted to the Charles R. Gow Company for courtesies extended to members this afternoon on the occasion of a visit to the subway under construction at First Street, Cambridge.

The discussion of the evening on "Engineers' Specifications from the Contractor's Point of View" was opened by Mr. James W. Rollins, Jr. Other members who took part in the discussion were: Messrs. Charles

G. Craib, Charles R. Gow, E. S. Dorr, L. S. Cowles, J. H. Gerrish, E. S. Larned, E. P. Adams and G. T. Sampson. The discussion was closed by Mr. Rollins, who read several letters which he had received bearing on the question.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

Boston, Mass., March 6, 1907. — The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Society rooms, Wednesday evening, March 6, 1907, with 31 members present.

The report of the Executive Committee was read by the chairman, and was accepted and placed on file.

The Clerk read a memoir of William W. Burnham, a member of the Section, who died August 11, 1906.

Upon motion of Mr. Sherman it was voted that a committee be appointed by the chair to nominate officers for the ensuing year. The chairman appointed H. P. Eddy, C. W. Sherman and E. W. Branch as members of this committee.

On motion of Mr. Farnham it was voted that a committee be appointed by the chair to oppose the passage of a bill now before the legislature for the extension of civil service laws to heads of municipal departments. Later in the evening this motion was reconsidered, and after considerable discussion it was voted to instruct the chairman to request the Board of Government of the main society to appoint a committee to consider the relation of civil service laws to engineers.

The committee appointed to nominate officers for the ensuing year reported and, in accordance with the instructions of the Section, the Chairman cast one vote for each of the following candidates, who were declared elected.

Chairman — Arthur T. Safford.

Vice-Chairman — Irving T. Farnham.

Clerk — William S. Johnson.

Executive Committee — George A. Carpenter, Lewis D. Thorpe, George E. Bolling.

The paper of the evening was presented by Arthur T. Safford, the subject being " Waste from Lowell Gas Light Company's Yard." The paper was discussed by Messrs. Barnum, H. W. Clark, W. E. McKay, George Bowers and others.

Annual Report of the Executive Committee of the Sanitary Section.

To the Members of the Sanitary Section of the Boston Society of Civil Engineers.

Gentlemen: Your Executive Committee reports with pleasure continued interest and activity in the affairs of the Sanitary Section. During the past year six meetings have been held, with an average attendance of 39 persons, as follows:

March 7, 1906, annual meeting, attendance 70. Papers, "An Account of Several of the Small Sewage Disposal Systems which have been Constructed to Protect the Purity of the Metropolitan Water Supply," by William W. Locke; "The Sewage Disposal Plant at Vassar College," by Ellen M. Richards; "The Sewage Disposal Plant at the State Colony for Insane at Gardner," by J. J. Van Valkenburgh; "The Sewage Disposal Plant of the State Normal School at Hyannis," by George H. Wetherell, Jr.

April 11, 1906, special meeting for the consideration of uniform sewerage statistics.

June 9, 1906, attendance 41. Excursion to the plants of the City Refuse Utilization Company and the New England Sanitary Product Company. Paper, "Modern Methods of Garbage Disposal," by William F. Morse. Dinner at the Point Shirley Club, Winthrop.

October 10, 1906, attendance 42. Paper, "The Relation of the Suspended Matter in Sewage to the Problem of Sewage Disposal," by H. P. Eddy, and A. L. Fales.

December 5, 1906, attendance 38. Paper, "The Maintenance of Sewage Filters in Winter," by G. E. Borden, E. C. Frost and E. R. B. Allardice.

January 9, 1907, attendance 43. Paper, "The Use of Small Pumping Plants in Connection with Sewage System," by I. T. Farnham, Lewis D. Thorpe and F. A. Barbour.

On November 11, 1906, Mr. Freeman C. Coffin, chairman of the Section, died, as previously reported to you. A memoir on Mr. Coffin's life was prepared, and resolutions of sympathy were passed, spread upon the minutes of the Section and sent to Mr. Coffin's family. Mr. Leonard Metcalf was chosen, on January 9, 1907, to fill the vacancy left by Mr. Coffin's death.

The subject of uniform sewerage statistics was carefully considered, and after a full discussion the report of the committee, recommending a form for the presentation of sewerage statistics, was adopted by the Section on June 9, 1906. It seems wise to call to the attention of members the desirability of the adoption, by municipalities and superintendents of sewerage plants, as far as possible, of this form for the presentation of sewerage statistics, in order that the results of operation and maintenance of these works may be as nearly comparable as possible. In this connection we call to your attention a letter written to Mr. M. N. Baker by Mr. L. G. Powers, chief statistician of the Bureau of the Census in the Department of Commerce and Labor, Washington, D. C.

DIVISION OF AGRICULTURE.
DEPARTMENT OF COMMERCE AND LABOR.
BUREAU OF THE CENSUS.

WASHINGTON, D. C., February 23, 1907.

Mr. M. N. BAKER, Expert Special Agent,
220 Broadway, New York:

Dear Mr. Baker, — Returning from New York on Thursday, I found your letter of the fourteenth instant on my desk, and in accordance with our conversation on this subject, I make formal answer thereto.

As stated in that conversation, it seems to me that the true position of the census with reference to the schedule of the Boston Society of

Engineers is as follows: The census office accepts that schedule tentatively as a basis of future work, and will proceed to make use of the same in the collection of data for its statistical publications so soon as a sufficient number of cities, through their engineering department, adopt that schedule in recording data.

They could further state in their report that the census is at present compiling statistics on sewers and sewage disposal which embody only a few of the most important facts called for by that schedule, and there are great breaks in those statistics owing to the imperfect classification, or want of classification, employed by the various engineering departments of the country.

I herewith return the letter from Mr. Johnson forwarded by you.

With best wishes, I am

Yours very truly,

(Signed) L. G. POWERS, *Chief Statistician.*

It is manifest that unless general use is made of the form outlined, the adoption of it by the Bureau of the Census cannot be hoped for, and much valuable information will thus be lost, or at least will remain unavailable to the great majority of those interested in this subject.

The present membership of the Section numbers: members of main society 156; Section members 29; total, 185.

Your Executive Committee bespeaks the active personal interest of every member of the Section in striving to increase the membership and the usefulness of the Section in every way possible. Many superintendents or managers of sewerage systems and sewage disposal plants are not at present enrolled upon the membership of the Section. Some means should be found of reaching these men and of impressing upon them the fact that men who have had practical experience in the operation of such works are particularly welcome, whether of technical attainment or not.

The Executive Committee will welcome suggestions for timely papers or topics for discussion, especially the latter.

Respectfully submitted,

LEONARD METCALF,
For the Executive Committee.

TWENTY-FIFTH ANNUAL DINNER.

The twenty-fifth annual dinner of the Boston Society of Civil Engineers was served at the Hotel Vendome, Boston, Tuesday evening, March 12, 1907, and was attended by 151 members and guests. The usual informal reception was held at 6 o'clock, and the dinner was served at 7 o'clock.

The special guests of the Society were Prof. Frederic R. Hutton, president American Society of Mechanical Engineers; Hon. William Berwin, acting mayor of the City of Boston; Hon. William A. Morse; Mr. Charles F. Knowlton, president Massachusetts Highway Association; Prof. Lucian I. Blake; and Mr. Charles Moore of the Submarine Signal Company. Music was furnished by the Albion Quartet.

At the conclusion of the dinner the President of the Society, Mr. Frank W. Hodgdon, introduced as the first speaker Professor Hutton, who brought the greetings of the American Society of Mechanical Engineers and spoke very interestingly of the new Engineers' Building in

New York City which had been erected through the munificient gift of Mr. Andrew Carnegie. Mr. Morse in an entertaining speech deplored the amount of accusation and ridicule that is now-a-days flung at anybody who has achieved prosperity or prominence. He particularly deplored the tendency to cast reproach upon the legislature of Massachusetts, which he believed at the present day is as good as it ever was, and better than most. Alderman Berwin brought the congratulations of the City of Boston and regretted that his Honor the Mayor was unable to be present. Mr. Charles F. Knowlton spoke particularly of the work of the Highway Association and of the great assistance which the civil engineer was to all who were engaged in the construction of streets.

An interesting incident of the dinner was a report made by Mr. F. P. Stearns of a call made that afternoon on Mr. Henry Manley, who was prevented from attending the dinner because of a slight indisposition. Mr. Stearns said that Mr. Manley for twenty-five successive years had been the Society's committee to arrange the annual dinner, and that on this anniversary it had occurred to some members of the Society to show their appreciation of his services by making him a slight gift. A gold watch and chain had been procured from voluntary contributions from such of the members as could be conveniently reached, and this afternoon the pleasing duty had been assigned him of presenting this gift to Mr. Manley. In accepting the gift Mr. Manley expressed his deep appreciation for the kind remembrance from the members of the Society and would at a later date try to express his feelings in fitting terms.

Boston, March 20, 1907. — The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President Frank W. Hodgdon in the chair, 60 members and visitors present. The record of the last meeting was read and approved.

Messrs. Edward Hutchins and Charles F. Knowlton were elected members of the Society.

The President read an invitation extended to this Society by the trustees of the United Engineering Society to participate, through an authorized representative, at the dedication of the building given by Mr. Andrew Carnegie as a home for American Engineering Societies, in New York City, on April 16 and 17, 1907.

On motion of Mr. A. H. French the invitation was accepted and the incoming president was requested to represent the Society at the dedication exercises.

The Secretary read the annual report of the Board of Government and, on motion, it was accepted and placed on file.

The Secretary read his annual report and, on motion, it was accepted and placed on file.

The Treasurer read his annual report and, on motion, it was accepted and placed on file.

Mr. Street presented and read the annual report of the Committee on Excursions. On motion, the report was accepted and placed on file.

The Librarian read the annual report of the Committee on the Library and, on motion, it was accepted and placed on file.

Mr. Johnson presented and read the annual report of the Committee on Advertisements. On motion, it was accepted and placed on file.

Mr. E. W. Howe made a verbal report for the Committee on Quarters.

On motion of Mr. F. P. Stearns the recommendation of the Committee on the Library in relation to the circulation of the books in the Society's library was referred to the Board of Government with full powers.

It was also voted, on motion of Mr. Stearns, to appropriate the sum of $50 for the purchase of standard engineering books.

On motion of Mr. F. L. Fuller it was voted to refer to the Board of Government, with full powers, the appointment of the several special committees of the Society.

President Hodgdon then addressed the Society, giving a very interesting account of some of the difficulties encountered in early surveys of the state of Massachusetts, how they were overcome and the results obtained.

At the conclusion of the President's address the tellers of election, Messrs. Nathan S. Brock and Henry B. Wood, reported the result of the letter ballot and in accordance with their report the following officers were declared elected:

President — Edward W. Howe.

Vice-President (for two years) — Francis W. Dean.

Secretary — S. Everett Tinkham.

Treasurer — William S. Johnson.

Librarian — Frederic I. Winslow.

Director (for two years) — Irving T. Farnham.

Before adjourning the meeting, the President introduced the President-elect, Mr. Howe, who thanked the Society for the great honor conferred upon him.

Adjourned. S. E. Tinkham, Secretary.

Annual Report of the Board of Government for the Year 1906–1907.

Boston, March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the constitution, the Board of Government submits its report for the year ending March 20, 1907.

At the last annual meeting the total membership of the Society was 621, of whom 584 were members of the Society, 2 honorary members, 13 associates and 22 were members of the Sanitary Section only.

During the year the Society has lost a total of 20 members; 7 by resignation, 6 by forfeiture for non-payment of dues and 7 have died.

There has been added to the Society during the year a total of 34 members in all grades, 33 by election and 1 transferred from the Toledo Society of Engineers. One of these is an associate and one is a member of the Sanitary Section only.

The present membership of the Society consists of 2 honorary members, 13 associates and 620 members, of whom 20 are members of the Sanitary Section only; making the total membership 635.

The record of deaths during the year is, John J. Howard, died May 18, 1906; Isaac K. Harris, died May 21, 1906; E. Elbert Young, died

June 1, 1906; John E. Cheney, died September 25, 1906; Nelson Spofford, died October 3, 1906, and Freeman C. Coffin, died November 11, 1906. At the time of his death Mr. Coffin was Vice-President of the Society and chairman of the Sanitary Section. William W. Burnham, a member of the Sanitary Section, died August 11, 1906.

Ten regular and one special meetings of the Society have been held during the year, and the Twenty-fifth Annual Dinner was given at the Hotel Vendome on March 12, 1907. The average attendance at the regular meetings was 66, the largest being 106 and the smallest 28. The attendance at the annual dinner was 151.

At the regular meetings the following papers have been read:

March 21, 1906. — Memoir of Dean C. Warren. Address of President John W. Ellis.

April 18, 1906. — Mr. H. A. Miller, "The General Features of the Charles River Basin and Dam." (Illustrated.)

May 16, 1906. — Prof. L. J. Johnson, "Reinforced Concrete Beams." (Illustrated.)

June 20, 1906. — Memoir of William T. Pierce. Prof. F. B. Sanborn, "Fires and their Prevention in Factories." (Illustrated.)

September 19, 1906. — Memoir of E. Elbert Young. General Discussion on Reinforced Concrete Construction.

October 5, 1906. — Continuation of Discussion on Reinforced Concrete Construction.

October 17, 1906. — Mr. Charles Moore, "The Submarine Signal." (Illustrated.)

November 21, 1906. — Mr. F. A. Kummer, "The Development of Wood Pavements." (Illustrated.) Mr. A. L. Plimpton, "Track Work in Washington Street, Boston."

December 19, 1906. — Memoir of Freeman C. Coffin. Mr. Paul Winsor, "Gas Engines and Producer Plants, as used by the Boston Elevated Railway Company."

January 23, 1907. — Mr. H. K. Higgins, "Replacement of Bridges and Allied Structures."

February 20, 1907. — Mr. J. W. Rollins, Jr., "Engineers' Specifications and Contracts from a Contractor's Point of View."

From the report of the Executive Committee of the Sanitary Section it appears that six meetings have been held, with an average attendance of 39. At all of these meetings interesting papers or discussions have been presented, which have been printed in the JOURNAL.

The Society has contributed $45 towards the rent of the hall, and has paid for the use of the stereopticon and for stenographic reports of the meetings, while the other expenses have been met by members of the Section.

At the beginning of the year the treasury was practically empty. The expenses for the preceding three years had been in excess of the income of the Society, the deficiency having been provided for by the balance carried over from previous years. It was plain that this could not continue, and the Board gave the matter immediate attention.

At the annual meeting it was thought that the only solution was either to curtail the expenses of the Society or to increase the income from advertisements inserted in the JOURNAL. If the expenses were decreased,

it would be necessary to curtail some of the work of the Society, and repeated efforts had already been made to increase the amount of advertising in the JOURNAL, but with little success. The net amount received during the past year was $198.12, and it was seen that but little could be expected from this source.

A Committee on Advertising was appointed by the Board of Government at the annual meeting, and to this committee is due the solution of the problem. At their suggestion the monthly notice mailed to each member of the Society, announcing the papers which are to be presented at the meetings, together with the names of candidates for membership, has been enlarged into the form of the present monthly bulletin, with which you are all familiar. The results were far in excess of anything which had been anticipated, as, after a few weeks, all the advertisements which could be reasonably used had been secured. The net income from these increased the income of the Society by about $800, double the amount necessary to provide for the anticipated deficit. The Board fully endorses the concluding portion of the committee's report which is as follows:

"It seemed to the committee, however, that in the *Bulletin* we have something better than an income producer. When the change in the monthly notices was proposed, it was at once evident that here was an opportunity to convey promptly to the membership certain information in regard to the Society and its library which heretofore had been lacking. It was decided to print in the *Bulletin* the records of all meetings, so that these records would be available to the membership much sooner than was possible when they were printed in the JOURNAL, and to make the library more valuable, a list of accessions has been published each month. A beginning has also been made towards publishing reviews of all new books added to the library. Thus has been started a publication which will be of real value and which will bring into closer touch with the Society those members who are not able to attend the meetings. There seems to be no reason why it may not be still further developed to contain, if not all the papers which are to be presented to the Society, at least such of them as can be secured far enough in advance for publication. With the experience of the past year your committee is convinced that this can be done without additional expense to the Society, as the advertising will more than pay the extra cost of publication."

The Board of Government believes that the practice begun some years ago of buying standard engineering books for the Society has proved beneficial, and would recommend that the sum of fifty dollars be appropriated for the purchase of such books for the coming year.

For the Board of Government,

FRANK W. HODGDON, *President.*

Abstract of the Treasurer's and Secretary's Reports for the Year 1906–1907.

CURRENT FUND.

Receipts:

Dues for 1906–1907	$3 935.50	
Dues for 1907–1908	59.00	
Sales of Journals	5.50	
Rent of rooms	1 000.00	
Advertisements	1 104.00	
Library fines	2.51	
Balance on hand, March 21, 1906	20.20	
		$6 126.71

Expenditures:

Rent	$1 995.00	
Lighting	46.81	
Association of Engineering Societies	1 472.99	
Printing, postage and stationery	936.21	
Salaries of Secretary, Librarian and Custodian	550.00	
Reporting meetings	163.37	
Stereopticon	65.00	
Annual dinner	74.00	
Books	50.28	
Binding	29.60	
Periodicals	30.50	
Clerical assistance for Librarian	34.00	
Furniture and repairs	35.40	
Incidentals	193.91	
Loan to Permanent Fund	63.95	
		5 741.02

Balance on hand, March 20, 1907	$385.69
Due from Permanent Fund	63.95
Amount to credit of Current Fund, March 20, 1907	$449.64
Amount to credit of Current Fund, March 21, 1906	20.20
Excess of receipts over expenditures during year	$429.44

PERMANENT FUND.

Receipts:

Thirty-two entrance fees, Society	$320.00	
One entrance fee, Sanitary Section	5.00	
Interest on deposits, savings bank	269.25	
Interest on bond	36.00	
Interest on deposit, Old Colony Trust Company	18.64	
Subscription to Building Fund	100.00	
Profits on shares in Co-operative Banks	496.05	
Loan from Current Fund	63.95	
Balance on hand, March 21, 1906	356.41	
		$1 665.30

Expenditures:

Merchants' Co-operative Bank, dues on shares......	$300.00	
Merchants' Co-operative Bank, profits on same.....	118.11	
Volunteer Co-operative Bank, dues on shares.......	300.00	
Volunteer Co-operative Bank, profits on same......	196.25	
Workingmen's Co-operative Bank, dues on shares...	300.00	
Workingmen's Co-operative Bank, profits on same..	181.69	
Franklin Savings Bank, deposit....................	42.71	
Warren Institution for Savings, deposit............	43.65	
Boston Five Cents Savings Bank, deposit..........	46.11	
Provident Institution for Savings, deposit..........	49.44	
Eliot Five Cents Savings Bank, deposit............	44.21	
Institution for Savings in Roxbury, deposit........	43.13	
		$1 665.30

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 20, 1907.

Twenty-five shares Merchants' Co-operative Bank............	$2 611.94
Twenty-five shares Volunteer Co-operative Bank.............	4 696.75
Twenty-five shares Workingmen's Co-operative Bank.........	4 315.17
Deposit in Franklin Savings' Bank..........................	1 252.88
Deposit in Warren Institution for Savings..................	1 280.49
Deposit in Boston Five Cent Savings Bank..................	1 352.47
Deposit in Provident Institution for Savings...............	1 450.12
Deposit in Eliot Five Cents Savings Bank..................	1 297.10
Deposit in Institution for Savings in Roxbury...............	1 265.30
Republican Valley Railroad Bond, par value.................	600.00
	$20 122.22
Due Current Fund..............................	63.95
Total value of Permanent Fund......................	$20 058.27
Amount of fund as per last annual report..............	18 813.33
Gain during the year..........................	$1 244.94

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund..................................	$20 058.27
Current Fund....................................	449.64
Total..	$20 507.91
Amount as per last annual report.........................	18 833.53
Increase during year..............................	$1 674.38

REPORT OF COMMITTEE ON EXCURSIONS.

BOSTON, March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

The Committee on Excursions herewith respectfully submits its annual report.

Thirteen excursions have been made during the past year, as follows:

April 18, 1906. — Charles River Basin and Dam. Attendance, 42.

May 16, 1906. — Inspection of the Plant of the Boston Bridge Works, East Cambridge. Attendance, 25.

May 24, 1906. — Inspection of Wonderland Park previous to its opening to the public. Attendance, 226.

June 20, 1906. — Lawrence Worsted Mills, Lawrence, Mass. Attendance, 12.

July 25, 1906. — Blake & Knowles Pump Co., East Cambridge, Mass. Attendance, 8.

August 3 and 4, 1906. — Portland Stone Ware Company, Portland, Me. Attendance, 125.

September 1, 1906. — Paragon Park. Attendance, 110.

September 19, 1906. — Sewage Pumping Plant at Deer Island. Attendance, 28.

October 13, 1906. — Simplex Pile Driving, N. Y., N. H. & H. R. R., South Boston. Attendance, 30.

October 17, 1906. — Submarine Signal Company, Boston Harbor. Attendance, 18.

November 21, 1906. — Paving work on Washington Street. Attendance 25.

February 20, 1707. — Pipe Tunnels under Broad Canal, Cambridge. Attendance, 11.

March 20, 1907. — Washington Street Subway. Attendance, 32.

Total attendance, 692; average attendance, 53.

Thirty-six pages of the "New Engineering Work" have been published in the *Monthly Bulletin* of the Society during the past year, as against twenty-four for the previous year.

There is a cash balance of $9.32 in the hands of the Treasurer.

The Committee wishes to thank all those who have aided in this work.

Respectfully submitted,

L. Lee Street, *Chairman*,
Eugene E. Pettee,
J. O. DeWolf,
Clarence T. Fernald,
Edmund M. Blake, *Sec'y and Treas.*,
Committee on Excursions.

Report of the Committee on the Library.

Boston, Mass., March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

The Committee on the Library begs leave to make the following report for 1906–1907.

Since the last annual meeting two hundred and ninety-seven (297) bound volumes have been placed upon the shelves. Of this number fifteen (15) books have been purchased and the remainder have been given to the Society.

During the year Mr. Clemens Herschel presented the Society with seventy (70) volumes. This splendid gift is now upon the shelves of the library and is a valuable addition.

Members have taken from the reading rooms for the purpose of reference two hundred and thirty-two (232) books during the past twelve months. This is an average of nineteen (19) per month, as compared with nineteen (19) per month of last year.

The present rules of the library allow a member to keep a book out five weeks. On account of the demand for some of the standard engineering text-books it seems that this period of five weeks is too long. If this rule is to be continued the Society should have several copies of some of the standard text or reference books in greatest demand, so that members of the Society may be properly accommodated. This solution of the problem, however, would entail considerable expense in the purchase of duplicate books, and a much better way is to reduce the time limit from five weeks to one week or else to limit the use of these standard engineering text-books to the reading rooms only. The committee recommends that the matter be referred to the Board of Government with power.

The committee also recommends that the sum of $50 be appropriated for the purchase of new reference or text books during the coming year.

Respectfully submitted,

Frank P. McKibben, *Librarian*,
Frank B. Sanborn,
Frederic I. Winslow,
H. K. Barrows,
Hector J. Hughes,
Committee on the Library.

Report of the Committee on Advertisements.

Boston, Mass., March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

The Committee on Advertisements submits the following report of its doings for the year ending March 20, 1907.

The Treasurer's reports for the past three years have shown an excess of expenditure over income, the excess during the year ending March 21, 1906, being over $400. The existence of a considerable balance has heretofore prevented a deficit, but at the beginning of the present year the balance had been reduced to $20.20.

The last annual report of the Treasurer contained the following warning:

> "It will be seen from the above that our income has not equalled our expenditure. This was also true of the previous year. The considerable balance on hand at the beginning of the year is now nearly exhausted. . . . It would seem, therefore, that the only practicable method of caring for the deficit is either by increasing the income from advertisements in the Journal or by reducing our current expenses."

It is plain that the expenses, which are practically constant, are capable of very little curtailment without impairing the usefulness of the Society, so that your Advertising Committee realized at the outset the importance of the task before them and that unless their efforts were

successful some way of decreasing the expenditures must be found or the annual assessment be increased.

Repeated efforts had already been made to increase the amount of advertising in the JOURNAL, but these efforts had met with but little success. The net amount received for advertising during the last year was $198.12. Experience has shown that few advertisers can be brought to see the value of an advertisement in a periodical such as the JOURNAL, which, in many cases, is not removed from the cover, and if removed from the cover is only to be put aside after an inspection of the table of contents.

It seemed to your committee, however, that the Society had a valuable advertising medium in the notices which are sent out each month, containing announcements of the coming meetings and excursions, the list of applications for membership and descriptions of new engineering work. These monthly notices are certain to be opened and read by practically every member of the Society, and advertisements in them are likely to reach a large proportion of the 600 members.

With the consent of the Board of Government the committee made arrangements for inserting a limited number of advertisements in these monthly notices, and the form of the notices was changed to the present *Monthly Bulletin*. The results were far in excess of anything which had been anticipated, and after a few weeks the committee ceased its labors, as it had a sufficient number of advertising contracts to insure a balance in the treasury at the end of the year instead of the threatened deficit, and it did not seem desirable to have too large a volume of advertising matter in the *Bulletin*. The contracts for advertising in the *Bulletin* amount to $1 120. No commissions have been paid and the only expense has been the extra expense of printing the *Bulletin*, which is in the vicinity of $300, making a total profit of about $800 for advertising. No effort has been made to secure additional advertising for the JOURNAL and the only income from this source has been from the renewal of contracts which had been previously made.

The efforts of the committee from a financial standpoint have been successful, and the treasurer's report shows, instead of a deficit of $400 which we had reason to anticipate, a balance of $400. It seems to the committee, however, that in the *Bulletin* we have something better than an income producer. When the change in the monthly notices was proposed it was at once evident that here was an opportunity to convey promptly to the membership certain information in regard to the Society and its library which heretofore has been lacking. It was decided to print in the *Bulletin* the records of all meetings, so that these records would be available to the membership much sooner than was possible when they were printed in the JOURNAL; and to make the library more valuable, a list of accessions has been published each month. A beginning has also been made toward publishing reviews of all new books added to the library. Thus has been started a publication which will be of real value and which will bring those members who are not able to attend the meetings in closer touch with the Society. There seems to be no reason why it may not be still further developed to contain, if not all the papers presented to the Society, at least such of them as can be secured for advance publication. With the experience of the past year your committee

is convinced that this can be done without additional expense to the Society, as the advertising will more than pay the extra cost of publication.

Respectfully submitted,

William S. Johnson,
F. A. Barbour,
S. E. Tinkham,
Committee.

Montana Society of Engineers.

Butte, Mont., February 9, 1907. — The regular meeting of the Society for the month of February, 1907, was held in the Society room at the appointed hour. Ex-President Dunshee presided. The minutes of the 20th annual meeting were read and approved. The application for membership in the Society of Harry Clifford Wilmot was read, and after its approval the Secretary was authorized to circulate the necessary ballot. Messrs. Lewis, McRae, Ring, Potter and Lindsay were elected to membership by a unanimous ballot. The trustees, to whom was referred the bill for a state geological survey, presented by Professor Bowman at the last meeting of the Society, made a verbal report, which was received. On motion the Society voted to endorse said bill for a state geological survey, now pending before the legislature of Montana. The Secretary was instructed to inform Representative Campbell, of Silver Bow County, who introduced the above-named bill, of the action of this Society in the matter.

The Secretary was authorized to forward the annual address of Ex-President Dunshee, and all other papers read at the annual meeting, as soon as obtained, to the Secretary of the Associated Societies for publication in the Journal at an early date.

The meeting then adjourned.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

Regular meeting held March 1, 1907.

Called to order at 8.30 o'clock by President Franklin Riffle.

The minutes of the last regular meeting were read and approved.

The Secretary explained in detail the steps taken to hold the spring meeting in the city of Vallejo.

He spoke of the points of interest that could be visited from there, mentioning the navy yard, Starr's Mills, the Suisun and Napa Junction Cement Works and the Selby Smelting Works.

Mr. Marsden Manson thought that the localities of Oroville and Chico held out greater advantages for technical men, and that a visit to the big dredges and the mines would be preferred by most of the members.

This matter was discussed for some time by the members present, and the Secretary was finally instructed to address a circular letter requesting a choice of locality from the members themselves.

He is to ascertain how many will attend, and, if the promised attendance be sufficient to warrant the excursion, the information then wanted is the choice of the locality for holding the meeting.

The circular is to include also a request for professional papers to be read at the sessions of the spring meeting.

The Secretary thereupon read a paper by Past President J. Richards, entitled "Fire Prevention Apparatus," which was discussed by written papers by President Riffle and Mr. Thos. Morrin; and verbally by Marsden Manson, Luther Wagoner and others.

Mr. Wagoner thought that a copy of the paper and of the discussions should be sent to the chief of the fire department of the city.

After an interesting general discussion of modern methods to apply salt water from the bay either by pumping from barges or pumping stations, in case of fires in the city front districts, the meeting adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XXXVIII. APRIL, 1907. No. 4.

Engineers' Club of St. Louis.

St. Louis, March 6, 1907. — The 630th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, March 6, 1907. President Fish presided. Twenty-three members and five guests were present.

The minutes of the 629th meeting were read and approved. The minutes of the 418th meeting of the Executive Committee were read.

The application for membership in the Club from Roy H. Pinkley was presented.

The Secretary read the following statement from the expert accountant instructed to audit the books of the Treasurer:

St. Louis, March 1, 1907.

Engineers' Club of St. Louis,
3817 Olive Street, City:

Gentlemen, — Attached hereto please find copy of statement covering operations from December 6, 1905, to December 5, 1906, submitted by your Secretary, dated December 5, 1906.

I have carefully examined the records for the period named, verified the statement and hereby certify its accuracy.

Yours very truly,
(Signed) Geo. W. Curry, *Accountant.*

The Secretary read a letter from the Civic League of St. Louis asking the Club to have representatives at a meeting to be held Saturday, March 2, in the office of the Business Men's League, to consider the need of a new charter for the city of St. Louis. The President of the Club announced that in response to this request he had notified the president of the Civic League that the Engineers' Club would be represented by Julius Pitzman, M. L. Holman and E. R. Fish.

The Secretary also read a most interesting and entertaining letter from Mr. O. W. Ferguson, a member of the Club, located in the Philippines. The Secretary was instructed to express the appreciation of the Club to Mr. Ferguson and to suggest to him that the Club would enjoy hearing from him as frequently as he finds it convenient to write.

Mr. Greensfelder moved that the Executive Committee be requested to examine Mr. Layman's presidential address with some care and make a report to the Club on the suggestions contained therein. Motion carried.

President Fish appointed the following Entertainment Committee: A. S. Langsdorf (chairman), R. L. Murphy, J. J. Lichter, Walter Robbins, S. D. Merton.

He also reappointed the Committee on Extension of Membership: W. H. Bryan (chairman), H. C. Toensfeldt, W. H. Henby.

Owing to the fact that Mr. Valliant was called east, he was unable to present his paper on the " Street Department; Its Organization and Its Work." Mr. Travilla and Mr. Childs had, however, prepared themselves to handle the entire subject in Mr. Valliant's absence, and a very entertaining and instructive discussion of the subject resulted. Mr. Travilla presented the legal side of the situation and the relation of the proposed changes in the charter to the work of the street department. Mr. Childs took up the bridge situation, methods of construction, length of life and cost of repairs, etc., for the different bridges and viaducts of the city. Both addresses were fully illustrated by lantern slides.

The discussion, which was participated in by Messrs. Pitzman, Von Maur, Toensfeldt, Harting, Fish, Fernald and Greensfelder, touched upon many points, such as the relation of the city to the sidewalks, the effect on the bridge construction of the steady increase in street car traffic, the overhead clearance above tracks, methods of laying and protecting gas service pipes in the streets, relation of the railway companies to bridge construction over their tracks and the effect of smoke upon bridges and methods of protection by means of paint, etc. Considerable discussion was provoked by the proposed new charter, some members even going so far as to desire immediate action on the part of the Club in this matter.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, March 20, 1907. — The 631st meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, March 20, 1907. President Fish presided. Forty-three members and thirty-two guests were present.

The minutes of the 630th meeting were read and approved and the minutes of the 419th meeting of the Executive Committee were read.

Mr. Roy H. Pinkley was elected a member of the Club.

An application for membership was presented by Mr. Carl L. Hawkins.

Mr. W. A. Baehr presented an exceedingly interesting illustrated paper on " Gas Engineering." The special points emphasized by Mr. Baehr are indicated by the following brief outline of the paper:

1. Brief historical outline of gas manufacture.
2. Mention of natural gas and its distribution.
3. Specific information concerning engineering of the manufacture and distribution of coal gas, water gas, by-product coke oven gas, producer gas, oil and blast-furnace gas, acetylene and miscellaneous.
4. The handling of material, types of apparatus, methods of distribution.
5. Thermal calculations concerning high temperature estimates.
6. Table of specific heats of gas at high temperatures, according to latest researches.
7. Specific data on the method of distributing gas in St. Louis.

8. Slides, showing drawings and photographs of various installations throughout the country.

The discussion, which was participated in by Messrs. Bryan, Robert Moore, McCulloch, Fish and Baehr, brought out the following points:

The question of deterioration of coal when stored either under cover or exposed to the weather was raised. It was stated that little data were available on this point. Mr. Baehr stated that the gas company did not find it necessary to store the coal under cover in St. Louis.

An effort was made to secure information relating to storing of coal under water.

In replying to a question regarding the relative advantages of water gas and coal gas, Mr. Baehr stated that the two are about alike. There is more hydrogen in the water gas and it is, consequently, not as good for gas engines, but either gas can be used for other purposes.

Other points which were touched upon in the discussion related to the life of gas mains, methods of protecting pipes under ground, methods of protecting from corrosion steel work in the retort houses and the possible use of gas for heating the water in hot-water heating systems.

Adjourned.

R. H. Fernald, *Secretary.*

The Civil Engineers' Club of Cleveland.

Annual Meeting, March 12, 1907, at Case School of Applied Science, called to order by President Miller about 9 p.m. Present: 52 members and 26 ladies and other visitors. Reading of minutes of previous meeting dispensed with, as was also reading of applications for active membership of Frederick D. Leslie and William Stanley Ferguson, both approved by the Executive Board.

The tellers, Messrs. Cadwell and Schowalter, reported the election of the following officers of the Club for the ensuing year:

President — Charles H. Wright.

Vice-President — Willard B. Beahan.

Secretary — Joseph C. Beardsley.

Treasurer — Walter M. Allen.

Librarian — Joseph R. Poe.

Directors (term expires 1909) — George T. Nelles, Andrew B. Lea: and the election of Sam. W. Emerson to active membership.

Printed copies of the financial reports of the Secretary and Treasurer were submitted and are appended hereto, as is also the Secretary's report on membership.

The report of Mr. Nelson, the Librarian, was read by the Secretary.

The President's address, "Recent Developments of Physical Science," was then given by Dr. Miller. It was an interesting history of the development of the electron theory of the constitution of matter and was illustrated by many beautiful and interesting experiments.

Before and after the meeting the members had the privilege of inspecting the new Rockefeller Physical Laboratory, which was opened for the first time to the public on this occasion.

Refreshments were served after adjournment.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Financial Reports of Secretary and Treasurer for Year Ending February 28, 1907.

secretary's report.

Permanent Fund.

Balance, March 1, 1906		$1 558.48	
Fees	$110.00		
Interest	64.04	174.04	
Transferred to General Fund			$600.00
Balance, February 28, 1907			1 132.52
Total		$1 732.52	$1 732.52

General Fund.

Balance, March 1, 1906		$11.68	
Dues, Active	$1 845.00		
Associate	112.00		
Corresponding	140.00		
Delinquent	110.00	2 207.00	
1905 Bills			$222.90
Advertising		116.00	20.80
Books and periodicals		5.00	22.75
Program		107.50	274.75
Incidentals			6.90
Journal		1.50	491.88
New quarters			459.02
Furniture and Fixtures			7.00
Reporting			10.00
Printing			270.93
Postage			90.10
Stationery			3.15
Associated Technical Clubs			742.50
Secretary			200.00
Telephone (extra name)			16.59
Taxes			11.34
Interest, $2.41; Miscellaneous, $1.75		4.16	
Transferred from Permanent Fund		600.00	
Balance, February 28, 1907			202.23
		$3 052.84	$3 052.84

Summary.

March 1, 1906, Balance, Permanent Fund	$1 558.48	
March 1, 1906, Balance, General Fund	11.68	
Receipts, Permanent Fund	174.04	
Receipts, General Fund	3 041.16	
Disbursements, Permanent Fund		$600.00
Disbursements, General Fund		2 850.61
February 28, 1906, Balance, Permanent Fund		1 132.52
February 28, 1906, Balance, General Fund		202.23
	$4 785.36	$4 785.36

Bills Receivable.

From members (dues)	$376.00

Bills Payable.

Associated Technical Clubs, January 1 to April 1, 1907	$247.50
The Warner & Swasey Co. (Periodicals)	14.65
Association of Engineering Societies	65.00
	$327.15

Respectfully submitted,

Joe. C. Beardsley, *Secretary.*

TREASURER'S REPORT.

Permanent Fund.

Receipts:			
Balance on hand March 1, 1906 .	$1 558.48		
Entrance fees	110.00		
Interest	64.04	$1 732.52	
Expenditures:			
Furnishing new club room		600.00	
Bal. on hand February 28, 1907,		$1 132.52	$1 132.52

General Fund.

Receipts:			
Balance on hand March 1, 1906 . .	$11.68		
From Sec'y, to February 28, 1907,	2 441.16		
From Permanent Fund	600.00	$3 052.84	
Expenditures		2 850.61	
Bal. on hand February 28, 1907,		$202.23	202.23
Grand total on hand February 28, 1907			$1 334.75

Respectfully submitted,

W. M. Allen, *Treasurer.*

Montana Society of Engineers.

Butte, Mont., March 9, 1907. — The regular meeting of the Society for the current month was held in the Society room, 225 North Main Street, on the above-named date at the usual hour. Ex-President Goodale presided. Quorum present. The minutes of the February meeting were approved as read. The application of Harry Hamilton Cochrane for membership in the Society was read, and after approval the Secretary was instructed to issue the necessary ballots. Harry Clifford Wilmot was elected a member of the Society by a unanimous vote. The request of the Technology Club of Syracuse, N. Y., for an exchange of club room and library privileges was read and granted. The Secretary of this Society was instructed to solicit the same favors from various engineering societies in behalf of any Montana Society engineers who may be temporarily situated where said societies are established.

The Society then adjourned.

Clinton H. Moore, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXVIII. **MAY, 1907.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, APRIL 3, 1907. — The 632d meeting of the Engineers, Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, April 3, 1907, at 8.15 o'clock. President Fish presided. Forty-eight members and twenty-six visitors were present.

The minutes of the 631st meeting were read and approved and the minutes of the 420th meeting of the Executive Committee were read.

The application of Edwin L. Smalley for membership in the Club was presented.

Mr. Carl L. Hawkins was elected a member of the Club.

The following resolution was presented:

" *Whereas*, there is under the auspices of the Civic League a movement under way looking toward the revision of the charter of the city of St. Louis, and as the members of this Club, both as citizens and engineers, have a great interest in this movement, and, having been invited to participate through two representatives in a meeting to consider ways and means to bring about such a revision, therefore be it resolved, that it is the sense of this meeting that a revision of the charter of the city of St. Louis is needed and advisable and that the President of this Club be instructed to appoint two delegates to represent the Club at such meetings as may be held under the auspices of the Civic League for the above-named purpose."

This resolution was adopted unanimously.

Mr. Robert Moore, who had just returned from a visit to Panama, presented a most interesting paper entitled " Notes of a Recent Trip to Panama." He discussed the canal project as originally proposed by the French and took up more or less in detail the development and changes in the proposed plans up to the present time. The paper was fully illustrated by maps, charts and lantern slides, which gave an excellent idea of the various plans proposed and the work that has been accomplished. Mr. Moore stated that of about 80 000 000 cu. yd. of earth moved by the French, only about 40 000 000 are usable, and that a large portion of the remainder will have to be rehandled. He gave a very complete description of the conditions on the Isthmus when the United States took the matter in charge. The tools and appliances found were obsolete, sanitary conditions bad and everything pertaining to comfort and safety from illness had to be carefully considered. There was little on the ground of service in this direction with the exception of about 2 000 small houses,

which were repaired and used. A good layout of hospitals was arranged among these houses. All food has to be brought in from the outside, as about the only thing raised on the Isthmus is bananas, and the supply of these is small. The government had to supply all necessary sanitary measures, police protection, hospitals, schools, churches, etc. At the present time there is a small government of its own on the Isthmus. The police arrangements are excellent and the general conditions are exceedingly satisfactory.

White labor seems to be very abundant. All the Italians and Spaniards desired can be secured. The white labor is proving much more efficient than black and the whites are receiving about three times the pay of the negroes. Mortality of the negroes is three to four times that of the white, pneumonia being the principal cause.

The early French proposition was for a canal about 29.5 ft. deep. Later plans increased this to 35 ft. and the present plan calls for 40 ft. The estimated cost of the proposed sea level canal is $247 000 000, requiring from twelve to thirteen years for completion. The plan, which is being carried out, *i. e.*, the lock canal, is estimated to cost $140 000 000. It is expected that this will be sufficiently completed for ships to pass through in eight years, *i. e.*, early in 1915. Not only is the lock canal cheaper, but the proposed construction will enable large ships to pass through much more quickly than would be possible with the sea-level canal.

Mr. Moore paid a high tribute to Engineer Stevens and to his corps of assistants, the latter including two members of the Engineers' Club of St. Louis, Messrs. Comber and Maltby.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, April 17, 1907. — The 633d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, April 17, 1907, at 8.15 o'clock. In the absence of the President, Vice-President Brenneke presided. Thirty-nine members and fourteen visitors were present.

The minutes of the 632d meeting were read and approved and the minutes of the 421st and 422d meetings of the Executive Committee were read.

The following applications were presented: James Stewart Kuhn for associate membership, Fred Oscar Pahmeyer for junior membership.

Mr. Edwin L. Smalley was elected member.

The recommendation of the Executive Committee that the committee be authorized to publish the Club's bulletin at an expense not to exceed $250 was approved.

Mr. W. H. Bryan, chairman of the Committee on Extension of Membership, made a complete report. The committee presented a list of approximately four hundred names of men who might be interested in the Club. The report made special recommendations regarding the methods of procedure in order to increase the present membership. It was moved by Mr. Greensfelder that the report of the committee be accepted and turned over to the Executive Committee for further action and the Committee on the Extension of Membership be discharged. Motion carried.

The committee appointed by the Club to assist in framing a set of regulations covering reinforced concrete construction in the city of St. Louis made a full report through its chairman, Mr. H. C. Toensfeldt. The report of the committee was accepted and the committee honorably discharged.

The business of the evening was devoted to a careful consideration and discussion of the specifications for reinforced concrete structures, prepared by the joint committee and embodied in the building ordinances of the city of St. Louis. These specifications had been printed by the Club and a copy sent to each member. They were taken up for discussion paragraph by paragraph, Mr. Toensfeldt, chairman of the committee, taking the lead. A spirited discussion resulted, and was participated in by a large majority of those present, Messrs. Purdon and Lindau having reduced their remarks to writing. Letters relating to this subject were received and read from Messrs. Viterbo and Traber. Mr. Greensfelder suggested the advisability of publishing this report and full discussion in the JOURNAL.

The Club adjourned at a late hour.

R. H. FERNALD, *Secretary.*

The Civil Engineers' Club of Cleveland.

REGULAR MEETING, April 9, 1907, at the Club rooms, called to order by President Wright, at 8 P.M. Present, forty members and visitors.

Minutes of two preceding meetings read and approved.

The tellers, Messrs. Neff and Wight, reported the election of Frederick D. Leslie and William Stanley Ferguson to active membership.

The application of Mr. Nathan C. Beckerman for active membership, approved by the Executive Board, was read.

The paper of the evening, "State Protection of the Purity of Inland Waters," was read by Mr. R. Winthrop Pratt, engineer of the Ohio State Board of Health.

The discussion was opened by Dr. Friedrich, City Health Officer, who held that with all possible freedom from contamination that could be obtained, there would still have to be filtration for all public water supplies, even where the supply was as ample in volume as it is where it is taken from a body as large as any of the great lakes.

Colonel Townsend, United States Engineer, told of the dumping of dredged material within less than 2 miles of the city's intake crib, much of this material coming from the river and being of fully as objectionable character as sewage. Mr. Rice told of the dumping of night soil in the same manner, and Messrs. Ritchie and Hoffman also took part in the discussion.

On motion of the Secretary the matter of the dumping of dredged material and night soil in the vicinity of the water works intake was referred to the Committee on Water Pollution for investigation and report.

On motion of the Secretary, Mr. Pratt was tendered a vote of thanks for his very able and interesting paper.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

Boston Society of Civil Engineers.

Boston, April 17, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President Edward W. Howe in the chair; seventy-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. George H. Brazer and Edward W. Hadcock were elected members of the Society.

The Secretary reported for the Board of Government the appointment of the following committees:

Committee on Excursions — L. Lee Street, E. M. Blake, C. T. Fernald, E. E. Pettee and L. B. Manley.

Committee on the Library — F. I. Winslow, Chas. Saville, N. S. Brock, H. E. Cowan and H. R. Stearns.

Committee on Quarters — Desmond FitzGerald, E. W. Howe, G. A. Kimball, F. W. Dean and F. W. Hodgdon.

Committee on Advertisements — W. S. Johnson, S. E. Tinkham and F. A. Barbour.

Board of Managers, Association of Engineering Societies — S. E. Tinkham, *ex officio*, Dexter Brackett, C. W. Sherman, G. A. Kimball, H. P. Eddy and A. T. Safford.

Mr. Fred. Brooks, for the Committee appointed to prepare a memoir of Nelson Spofford, a member of the Society, presented and read its report.

Mr. George B. Francis read the paper of the evening, entitled "Pennsylvania Terminal Station in New York City, and the Engineering Problems Connected Therewith." The paper was illustrated by a large number of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., April 13, 1907. — The regular meeting of this Society for April was held at the called time and place. Trustee Wilson presided. Attendance good.

Minutes read and approved.

Harry Hamilton Cochrane elected to membership by a unanimous vote.

Application for membership in Society of James Humes read, approved and ballots ordered circulated.

Several letters from societies granting request of this Society for exchange of library and reading-room privileges read and appreciated. Society adjourned.

Clinton H. Moore, *Secretary.*

Association of Engineering Societies.

Vol. XXXVIII. | JUNE, 1907. | No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 1, 1907. — The 634th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, May 1, 1907, at 8.15 o'clock. President Fish presided. Twenty-seven members and ten visitors were present.

The minutes of the 633d meeting were read and approved.

The application of Mr. William B. Ittner for associate membership was presented.

Mr. James Stewart Kuhn was elected an associate member and Mr. Fred Oscar Pahmeyer, junior member.

The paper of the evening was by Mr. W. H. Rohwer on "Deep Foundations for Bridges and Buildings." The author reviewed the entire subject of deep foundations at some length, and described in detail some of his own work in this field, notably the foundations for the Arkansas River and White River bridges. A discussion was called forth by the paper, which was participated in by Messrs. Purdon, Henry, Flad and Greensfelder.

Adjourned.

Hans C. Toensfeldt, *Secretary pro tem.*

St. Louis, May 15, 1907. — The 635th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, May 15, 1907, at 8.15 o'clock. President Fish presided Sixty members and thirteen visitors were present.

The minutes of the 634th meeting were read and approved.

Prof. A. S. Langsdorf, chairman of the Entertainment Committee, made an informal report regarding proposed trips to Washington University and to the plant of the Illinois Glass Works.

The following applications were received: Schantl, Hans (member); Sweetser, Ernest Osgood (member); Morrison, Henry Craig (Junior).

Mr. F. B. Maltby, principal assistant engineer Isthmian Canal Commission, presented an unusually interesting and instructive paper entitled "Progress of the Work on the Panama Canal under the Administration of Mr. J. F. Stevens." Many queries were made of Mr. Maltby

regarding conditions, etc., in the canal zone, the discussion being participated in by Messrs. Fish, Layman, Trepp, Barwick, Robert Moore, Flad, Hinckley, Bouton and Hoffman.

Adjourned.

R. H. Fernald, *Secretary.*

Boston Society of Civil Engineers.

Boston, May 15, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President Edward W. Howe in the chair, 81 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Thomas F. Bowes, Charles S. Bryer, Frederick A. Leavitt, Ernest M. Moses, Daniel Scouler, Jr., and Harrie L. Whitney were elected members of the Society.

Prof. George F. Swain, for the committee appointed to prepare a memoir of John E. Cheney, a member of the Society, presented and read its report.

The President announced the deaths of Charles H. Haswell, an honorary member of the Society, who died May 12, 1907, and Frank W. Upham, who died May 3, 1907. By vote the President was requested to appoint committees to prepare suitable memoirs. The following committees were appointed: On memoir of Mr. Haswell, Messrs. Desmond FitzGerald, Clemens Herschel and Ira N. Hollis. On memoir of Mr. Upham, Messrs. I. T. Farnham and Rowland H. Barnes.

Mr. Thomas MacKellar read the first paper of the evening, entitled, "The Simplex System of Concrete Piling." Mr. Charles R. Gow read the second paper, which dealt with the general subject of concrete piles. Both papers were illustrated with lantern slides.

In the general discussion which followed the reading of the papers, Mr. Frank B. Gilbreth, in response to an invitation of the President, spoke briefly of his experience in driving concrete piles. He also spoke of the large amount of concrete work now being done at San Francisco, and expressed his regrets that so much of it was in the hands of men who were inexperienced in this kind of work.

Adjourned.

S. E. Tinkham, *Secretary.*

Toledo Society of Engineers.

Toledo, April 12, 1907. — Meeting called to order at 8.20 p.m. by Vice-President H. E. Riggs.

Secretary read the minutes of the Society meeting of March 8, 1907, which were approved as read.

Secretary then read the report of the Board meeting of April 5.

Chairman of Finance Committee, Mr. C. L. Gates, being absent, the report of that committee was read by the Secretary and accepted as read. (See report on file.)

Mr. Davis, chairman of Publication Committee, read report of that committee, which was accepted as read. (See report on file.)

Library Committee, Mr. H. E. Riggs chairman, reported no meetings of committee held since new order of business.

Mr. Davis, as chairman of Furnishing Committee, reported that an order had been placed with the Lion Store for a full set of curtains, but they were one pair short, which had been ordered from the mill but had not yet arrived.

Under new business:

Committee on Annual Banquet reported. (See report on file.) Mr. M. J. Riggs moved that Publication Committee arrange for annual banquet, time, place and all details to be settled by committee. Mr. Davis called for suggestions as to expenses, etc., in regard to banquet.

The motion being put, it was unanimously carried.

The chairman of the evening, in a few well-chosen remarks, then introduced Mr. Faro Gage, of Columbus, who spoke on the subject of "Civic Improvements." (See paper on file.) Mr. Gage was heard with a great deal of interest and his paper highly appreciated by those present.

The chairman then introduced Mr. E. O. Fallis, who read a paper on the subject of "Municipal Improvements." This paper was illustrated with very instructive stereopticon views. (See paper on file.) After Mr. Fallis' paper a lengthy and interesting discussion took place, in which Messrs. Fallis, Gage, M. J. Riggs, Sherman, Gates, Tonson, Langdon and Hiett took part. Mr. Brumback, of the Chamber of Commerce, spoke with emphasis on the subject of Civic Improvements as concerns the Chamber of Commerce. He was followed by Mr. Dunham, clerk of the Council, who gave the views of the Council on this subject.

Mr. M. J. Riggs moved that the chairman appoint a committee of three or four to confer with the Chamber of Commerce on the above subject. This motion was seconded and carried unanimously. Chairman appointed Messrs. Fallis, M. J. Riggs, Davis, Sherman and Gould.

There being no further business, the meeting adjourned.

JOHN C. OLIPHANT, *Secretary.*

JOURNAL

OF THE

Association of Engineering Societies.

St. Louis. Pacific Coast. Louisiana.
Cleveland. St. Paul. Detroit.
Toledo. Boston. Montana.

CONTENTS AND INDEX.

VOLUME XXXIX

July to December, 1907.

PUBLISHED MONTHLY BY

Fred. Brooks, Secretary of the Board of Managers of the Association of Engineering Societies.

31 Milk Street, Boston.

CONTENTS.

VOL. XXXIX, July–December, 1907.

For alphabetical index, see page v.

No. 1. JULY.

No. 2. AUGUST.

No. 3. SEPTEMBER.

No. 4. OCTOBER.

INDEX.

VOL. XXXIX, July–December, 1907.

ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIX. JULY, 1907. NO. 1.

ENGINEERS' CONTRACTS AND SPECIFICATIONS FROM A CONTRACTOR'S POINT OF VIEW.

BY JAMES W. ROLLINS, JR., MEMBER OF BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, Feb. 20, 1907.]

ACCORDING to Mr. John Cassan Wait, an authority on engineering contracts, the essential elements of any contract are as follows:

First. Two parties with capacity to contract.

Second. A lawful consideration.

Third. A lawful subject matter.

Fourth. Mutuality: a mutual assent, a mutual understanding, a meeting of the minds of the parties.

This fourth element is the one which most appeals to me to-night, and to which I shall devote most of my time.

A mutual understanding, that is, each of the parties to the contract is to know and understand as nearly as possible just what is meant for each to do, and to this end the contract must be explicit in all its terms.

It is supposed as a basis of argument that both of the parties are fairly disposed towards one another, neither to try to gain an advantage, and that all acts are as *between man and man.*

A contractor must base his figures on definite information, or else make some wild bid, the degree of wildness being in accord with the risks to be run. On some contracts this element of uncertainty must be large, and the writer believes this to be the only class of work properly done on a percentage (or cost plus) basis. But also in very many other contracts there are

many uncertainties injected; some dependent on the wording of certain clauses, from which the contractor's only hope of salvation is the fair-mindedness of the engineers; and here the man, knowing the engineer and his way of handling work, has the advantage over the stranger.

For instance, quoting from an existing contract, — "Excavations shall be made of dimensions indicated upon the plans, where dimensions are given, *except as otherwise directed.*"

"Piles shall be driven not below elevation 102, and shall be cut off at these levels unless *otherwise directed.*"

In the first case quoted, plans showed excavation to -28, and then comes in the "otherwise directed" clause by which excavation could be made to -50 if desired, at no extra price to contractor.

Under the pile clause, they may be cut off anywhere.

Referring to another contract — for a dam — "if excavation is required below a certain grade, a special price is to be paid for such work."

Which of these clauses do you think the most fair, and can you suggest any reason for putting such uncertainties into a contract, without provision for a just and proper payment for the work done?

The very customary clause in a contract, which makes the chief engineer the sole judge of everything, the quality of work, the amount done, and the value of it, appears to us to be a most unjust clause, and one entirely out of the spirit of mutuality which has been referred to. The need of an arbitrator does not come until parties in interest have disagreed, and then under this clause one of them settles it "for good and all." It takes a true and good man to be entirely just in settling a row in which he has been a participant, and may have even been "knocked out" in the first round. It is not uncommon to hear of engineers "who will get even with contractors."

A more just and proper clause is such a one as this, which is now quite common with engineers, and is a standard clause in architects' contracts:

"Should any dispute arise concerning the true construction of the plans or drawings and specifications hereinafter mentioned, or any part of either, the same shall be decided by the said engineers, and their decision shall be final; but should any other difference arise between the parties of the first and second parts, the same shall be submitted to the arbitration of two competent and disinterested persons, one to be named by the party of the first part, and the other by the party of the second part, which

two in case they cannot agree may choose an umpire; and the decision of the arbitrator, or the umpire, shall be binding and conclusive on all the parties hereto.

"It is on this same ground of public policy, that agreements by contractors to abide the decision of the engineer as final and conclusive without recourse to courts of law or equity have been declared not binding — illegal and void. The courts have held that the Government guarantees to every man the protection of the courts and their assistance and that no man can enter into a contract that shall deny him this privilege and right."*

On the mutuality basis, the absolute disclaimer of any responsibility for the accuracy of borings seems unjust. Many of our large water jobs give us extensive and detailed plans of borings, and contractors must necessarily base their figures on them. If these borings prove to be wrong, and the contractor suffers thereby, why should not this be borne by the owners? It is not a contingency figured on by the contractor, and in all faith and justice he should not suffer. He has to take chances on the winds and the floods, the frosts and the thaws, the acts of God and the perversity of man, of quicksand and other classes of excavation; so why should be added to all these the errors of "borists," and they make many?

When we drive piles through 20 ft. of solid rock, or 50 ft. through "sand and gravel, very hard," and have figured on short piles, we have a spirit of "kick" in us, and think someone should pay the price. You engineers all say, "We gave you the results of the borings out of the spirit of our hearts to help you, and we thought them correct; so you shouldn't look a gift horse in the mouth and complain, but should take your medicine." Here the "mutuality" comes in; the basis of the contract was wrong. It seems to me it is one of the items of common misunderstanding, which might be eliminated.

Every contract to-day affords ample protection against unjust claims for extra work; most engineers check up all costs of such, and by the contract, bills for same must be rendered monthly; so how is it possible for any great "graft" to come in with such claims?

Clauses in contracts which in any way give the engineer control over the methods to be used to do the work, or those which throw the responsibility of the work designed by the engineer on to the contractor, are great sources of trouble. This means divided responsibility, and this, as sure as fate,

* Wait's Engineering and Architectural Jurisprudence, page 76.

trouble; for no two men, especially a contractor and an engineer, can exactly agree upon methods of doing work.

We are, to-day, at work on structures, every detail of which was designed by engineers; they have reserved the right to tell us in detail exactly how to do everything connected with it; and on the end of the contract clause are the words, "*the contractor shall assume all responsibilities in the work, and for the stability of the structure.*"

What do you think of that? But one thought can come to you, and that is, we must be idiots to sign any such contract. In a great measure we are idiots, but we have to run chances other than acts of God, etc., and that is, I am glad to say, one chance we rarely lose, that the engineers are fair and honorable men in settling matters of this kind.

You all know of the trouble from such a clause in the Charlestown Dry Dock, where the contractor was to submit a plan for cofferdam satisfactory to the engineer. He submitted one, of the most common and efficient type, but it was not approved. After many delays a plan was approved, the dam built and *failed*, and there are now pending claims of hundreds of thousands of dollars against the Government, on account of this failure.

Personally, the writer fails to see why any engineer wants to assume the responsibilities of others, and, where his clients are protected by suitable bonds, why he doesn't let the contractor go ahead and make his own plans and work out his own salvation, or damnation, as he will.

A clause from a Boston Transit Commission contract bears on this subject:

> "But neither the Commission, nor any member of it, nor the engineer, etc., shall have any control or direction over the progress of the work, nor any control or superintendence over the apparatus, ways, works, machinery or plant; the sole responsibility for the proper handling of which, as well as for the safe and proper conduct of the work, resting solely with the *contractor.*"

Inasmuch as this commission's work was done under very expensive buildings and the city streets, where great trouble, loss of property and life, were possible, it seems to me that the commission showed its good sense by keeping clear of the "ways and means," and the temporary work, and letting the contractor do the work his own way and assume the responsibility.

The only time we came near trouble in the Charles River

cofferdams was due to the divided responsibility, we thinking the inspector was on to his job, and the dam engineers thinking it was our cofferdam, so neither kept track of a certain section and left some very necessary bolts out.

On this job where we are under $150 000 bonds and the commission has $60 000 in reserved percentage, it wants us to build a temporary structure on its design and at our risk. Inasmuch as this structure has a factor of safety of about twelve, we do not feel troubled at taking this responsibility, but still we object strongly to the principle.

Another clause in many contracts: That the engineers may shut down the work at any time and for any reason and the contractor has no redress. This clause must have had its origin in old railroad construction, where the question of right of way, or of alignment was always uncertain, and it has been perpetuated to-day to our great sorrow and many times our loss. Here again the mutuality comes in, the contract was let in good faith, with no idea of any delays for anything.

To insure the completion "on time" the lawyers — I don't think the engineers ever coined any such expressions — meekly say, "Time is of the essence of this contract, and you shall pay $100 a day, not as a penalty, but as liquidated damages." We know what liquids are and what damages may be, but we haven't been able to find the difference to our pocketbooks between "liquidated damages" and a "penalty."

Hence the proposition: We must finish on time or pay $100 a day, but the commissioners can hold us up for any length of time and pay us nothing for the loss to us for this delay. We build special plant to do the work, get men trained to do the work properly and well; then comes the order to stop, shut down the plant and discharge the men. The plant cannot be moved, but must stay idle, new men must be trained over again; if work is done on a rising market, if labor demands more pay, we pay it, and all this loss comes on the contractor. Why should it? We didn't figure on it. It is a contingency unseen, and in all justice payments should be made on the *mutual understanding basis.*

Not content with the general obnoxious and unjust conditions mentioned, which are very common in contracts, often special provisions are made, which put most extraordinary powers in the hands of the engineers, and as they are hastily read over by the contractor, do not mean much. For example:

"The said contractors hereby declare and agree that they shall be accountable for the full performance of this contract, and by the signing hereof admit that the said plans, elevations, sections, specifications and parts before referred to are sufficient for their intended purpose of doing the said work, and that the work can be successfully executed in accordance therewith without any additional or extra work other than that set forth thereby or necessarily inferred to be done from the general nature and tendency of the plans, drawings and specifications aforesaid upon a fair and liberal construction thereof."

This innocent clause cost us on one contract $10 000. We took a contract to rebuild two abutments and one pier for a river bridge. The plans, not very complete, showed the new abutments to be about 18 in. clear behind the old work, which had to remain in place until new work was built. These abutments were 36 ft. high; and when excavation got down to water level it was found that the old work was thicker than the plan showed, and left no room to put in cofferdam between it and the new work. It cost $10 000 to get the lower 4 ft. of these foundations, owing to the inability of making cofferdams tight.

We protested to engineer on first abutment, but to no avail, asked that other abutment be "fudged" back 2 ft., an easy matter, but no change was allowed. Work was finally completed and demand made for extra pay for work, on account of errors in plans; was not granted, and was then left to be arbitrated as contract provided, the chief engineer meanwhile *insisting* that his company or his office was not at fault, or liable; and this clause was then brought out by our own lawyers, and we were advised that we had assumed all responsibility in the matter and had agreed that the plans were sufficient to do the work called for, with no extras.

Later on this same contract we deposited concrete under water, and after a month it proved worthless, and examination showed that the river water was polluted to such an extent as to destroy the cement: to do the work then required a cofferdam to be driven for pier in the middle of the river, the water pumped out and masonry substituted for concrete.

Again was this clause brought to our attention and our counsel advised it was very doubtful whether we could recover in court, even though the contract in a way required an impossibility.

It is a general impression among engineers that clauses requiring impossibilities are null and void and that a court would not recognize them; but the law on the case is very

deficient and the cases tried in this country very limited. These cases always go back to a London bridge case, Thorn *v.* Mayor of London, which was as follows:

" Defendants being about to erect a bridge an engineer prepared for them, at their request, plans and specifications both of the bridge and of the mode in which it was to be constructed.

" The plaintiff on the faith of these plans and specifications and without any independent inquiry whether the work could be done as specified, entered into contract with the defendants to do it in accordance with the terms of the plans and specifications. After the plaintiff had incurred great expense it was found that the work could not be executed in the manner specified. The plaintiff sued the defendant on the ground of an implied warranty by them that the work could be executed in the manner described in the plans and specifications.

" Held that no such warranty could be implied.

" This bridge, Blackfriars Bridge, was built about 1864 across the Thames. By a clause 54 the contractor was to satisfy himself as to the nature of the ground through which the foundations were to be carried; it was stated that all the information given on this subject was believed to be correct, but was not guaranteed.

" The caissons built according to plans and specifications were not strong enough to resist the pressure, so that a large part of the work had to be done at low or half tide, thus causing great delay and additional cost.

" The Court seems to lay the blame on the contractors on the ground that it was their duty to examine for themselves the question whether the method of the engineer for the city was right or not.

" This case went up finally to the House of Lords.

" The Lord Chancellor (Cairus) said, in giving his opinion, ' Mr. Corbitt (engineer for the city) considered that the bridge could be built in a manner somewhat, if not altogether, modified by the use of caissons in place of cofferdams, and the specifications and drawings were made on that footing.' "

[So it would seem that the engineer for the city made an experiment and the contractor paid for it.]

There was a provision in the contract for payment for extra work.

Only the upper part of caissons had to be abandoned by reason of the great pressure, which necessitated doing of the upper part of the work at low or half tide when it could be done.

All the judges (in the House of Lords) concurred; and they all seem to agree that it was the contractor's duty before making the contract to satisfy himself that the work could be done efficiently under the plans and specifications furnished by the city; all engineers, they say, are liable to error.

[Why not the engineer for the city as well as the contractors?]

This case has been much commented on both in England and in the United States.

The judgment in the House of Lords, however, leaves it an open question whether the plaintiff (contractor), assuming the extra work not to have been extra work of the kind contemplated by the contract itself and to be paid for under it, might not have recovered for it as a *quantum meruit* (*i.e.*, as per services rendered for the benefit and at the request of the plaintiff though not under an express contract).

A Recent Opinion of the Court on the Question of Executing an Impossibility.

The Court in the opinion stated that the delay was one due to the contractor's error of judgment, and that there appeared to be no ground upon which he could ask to be excused from the consequences of his own mistake. The Court cited with approval the rule expressed in the case of Chicago, etc., Railway Company *v.* Hoyt (149 U. S., p. 14), which is as follows:

"There can be no question that a party may, by an absolute contract, bind himself or itself to perform things which subsequently become impossible, or pay damages for the non-performance, and such construction is to be put on an unqualified undertaking where the event which caused the impossibility might have been anticipated and guarded against in the contract, or where the impossibility arises from the act or default of the promisor. But where the event is of such a character that it cannot be reasonably supposed to have been in the contemplation of the contracting parties when the contract was made, they will not be held bound by general words which, though large enough to include, were not used with reference to the possibility of the particular contingency which afterwards happens."

In another case of work we did, this application of an impossibility clause came in as follows:

Plans showed 6 in. hard pine sheeting driven to a depth of – 20, and specifications said simply, "Sheet piling shall be driven as shown on plans"; and no borings or samples were shown, and no mention made of material or the possibility of hard driving, though the ground showed sand.

Before we got ready to do our work other contractors had driven sheeting of same kind for a trench, and their work, though done under much easier conditions (*i.e.*, with sheeting driven only a little ahead of excavation in trench), showed the timber to be seriously crippled by the gravel stratum into which

it was driven. Our line of sheeting was to act as a permanent bulkhead, and to be of any value should be put into place without crippling. We tried all sorts of ways to get the sticks down, with a jet and otherwise, and finally gave up the attempt on the assurance of the engineer in charge that, in his opinion, we could not *drive it* in a way satisfactory to him.

We took up the "impossibility plea" and were gently advised by the owners that in the opinion of their lawyers we agreed to drive that sheeting as shown on plan, and that we must do this, even though the material was rock and we had to bore holes to put the sheeting into.

We finally dredged the gravel out, drove our sheeting, back-filled it, finished the work, the company paying us, I think, cost of dredging.

But these cases put all the burden of unforeseen things on the poor contractor, and when trouble comes, the engineers refer the matter to the lawyers and they interpret the law, not by right or justice, but the strict legal meaning of the contract, and I venture to say that not a single contract is made to-day on large works, which does not give the engineer power enough to put the contractor into bankruptcy by such clauses as I have been quoting. All this is unnecessary. Every contract has a provision for extra work and for the filing of all claims for damages, change of plans, etc., with engineer once a month, and the right of engineer to see all papers connected with these claims. They cannot be collected by demand of contractor, but only at last resort by a court of law, which in our free country is the court of last resort to all injured souls. So why should not contracts be made which give the contractor some rights to a settlement other than by the man he cannot agree with, by some disinterested person who can do justice, having some regard to the old principle of man-to-man settlement?

"Every unnecessary or unfair clause in a specification has its part in limiting competition, and in lowering the standard of honesty among contractors. A clause that may be used as a club can be avoided in one of two ways, either by not bidding on work governed by the clause, or by using 'graft' to insure that it shall be a dead letter."

Many contracts to-day show the improvements which we wish to become more general, and eliminate the clause which makes the engineer the final judge of all things, substituting settlement of disputes by arbitration. This is a great step

forward, and we trust that the other few clauses which make trouble, when trouble comes, may be eliminated.

The courts now lean towards the "intent" of the parties making the contract, the "mutual understanding," between the contracting parties. This means that the contractor shall do what the plans and specifications call for in a fair and just interpretation and under the conditions which at the time of making the contract seem to be most probable, and such understandings must bar out the particularly objectionable clauses as follows:

First. Disclaiming responsibility for soundings or other information as to the character of the work.

Second. The insertion of clauses which make any contractor's estimates worthless by adding, "or as otherwise directed."

Third. Making the contractor responsible for work for which engineers make the plans or require their approval to any made by contractor, and where engineers reserve the right to entirely control the manner and means of construction.

Fourth. Holding contractor responsible for work which has passed inspection or has been done under direction of engineer, or his agent, or inspector, unless fraud can be proved.

Fifth. Making the engineer the sole referee in settling all claims.

Sixth. The right to stop work, or any part of it, if for the interests of the company so to do, without allowing the contractor anything for the loss such action might bring to him.

When these clauses are eliminated and others substituted which give the contractor the benefit of the "intent" of the contract, and which will insure a settlement on that basis by disinterested parties, then comes the day of freedom for contractors.

I commend to you the *Engineering News*, on whose editorial staff is some writer on this subject, with whose sentiments I most heartily agree. He says:

"We wonder whether, if contractors were treated with something like a square deal in letting contracts, there might not be less temptation to graft in their execution."

The following comments on two specification clauses relating to extra work, made by correspondents in *Engineering News*, are of interest:

"We have had occasion to criticise certain specification clauses relating to payment for extra work, because of their failure to define what was meant by the expression 'actual cost plus 15 per cent.' The following clause from a recent sewer

specification is, in this respect, the most definite of its kind that we have seen:

" ' Extra work ordered in writing by the board or the engineer will be paid for at the reasonable and actual cost of the same plus 15 per cent. for profit, superintendence and general expenses. The said cost of the extra work shall include all fuel, materials and labor furnished by the contractor, but it shall not include office expenses, general superintendence, salaries, use of tools or machinery or other general expenses.'

" There seems to be some doubt whether, under this clause, the cost of ' bossing ' the job is included or not. General superintendence is specifically excluded, but nothing is said as to foremen, unless we take the word ' salaries ' to include all men paid by the week in distinction from men paid by the day. Foremanship may itself run from 5 per cent. to 15 per cent. of the total cost of small engineering works, so that it is important to include it specifically in the items of ' actual cost ' to which the 15 per cent. is to be added. It is immaterial whether the foremen in charge of separate gangs of men are paid by the day, by the week or by the month, hence the word ' salaries ' if used at all in a specification should not be made to include the foremen who are bosses of individual gangs.

" Now a word as to the specified percentage to be added for profits. It has been the experience of a well-known contractor with whose records we are familiar, that on sewer work the general ' expenses ' (exclusive of foremanship) seldom amount to less than about 7 per cent. of the total cost, and that the wages (or salaries) of bosses will average another 10 per cent.

" The insurance of sewer laborers amounts to several per cent. of the payroll. Indeed, there are cities where the soil is so treacherous that surety companies fix premium rates that are practically prohibitive. One cave-in may wipe out several thousand dollars' worth of premiums, by causing the death of a man.

" We see, therefore, that there are conditions under which 15 per cent. added for profits is in reality 15 per cent. added for expenses that are as actual as the weekly payroll. Each piece of work must be considered by itself in specifying the percentage for profits, but in all cases the cost of foremen should be included.

" Where an expensive plant is likely to be required, it may be desirable to specify a certain percentage of the first cost of the plant to be allowed for ' plant rental,' and considering this ' plant rental ' as an item of the ' actual cost.'

" It will be noted that fuel is included as an item of ' actual cost.' This should always be done, as fuel is often an important item, and its cost is readily ascertainable." * * * *

" The same specification from which the foregoing clause was abstracted contains the following:

" ' The Commission reserves the right to increase or decrease the work, or to stop the work, wholly or in part, at any time. Nor will the Commission be liable for any loss or damage to the contractor because of any stoppage of the work.'

"A number of complaints from contractors contemplating bidding upon this work seem to justify giving space to this clause, in spite of the fact that similar clauses have been previously discussed in the columns of this Journal. It appears not to have occurred to the author of this specification that the element of time is a factor of importance to a contractor, or that the amount of work to be done affects the unit cost, or that there is any unfairness in a specification that permits one party of a contract to escape from the implied obligations while rigidly holding the other party to performance. Nor does it seem to have been regarded as possible that some contractors might hesitate to buy a plant or part of a plant to do work which may be shut down before the plant has been in operation long enough to pay the freight from the factory. Every clause like this brings its own punishment either by causing only a reckless class of contractors to bid or by causing conservative contractors to bid an exceedingly high price to cover risks. There are internal evidences of lawyer authorship of these specifications; and it is not improbable that if an engineer ever had a hand in the original draft, he has been forced to see all semblance of fairness wiped out by a few legal, but foolish, pen strokes; for it is an economic folly to attempt to play fast and loose with intelligent and reliable contracting firms.

"A clause governing the excavation of rock for a dam site has some interesting and self-contradictory features to which attention may well be called. It reads as follows:

"'In this excavation the kind of explosives used, the amount of the charges, the depth and direction of the holes and the entire process of the work shall be under the control of the engineer, the object being to do the work in such a manner as to avoid fissures in the remaining rock.

"'If at any place the contractor shall excavate, damage or shatter the solid bed rock beyond the lines given by the engineer to be excavated, and it is necessary to replace the solid rock by masonry, then the contractor shall supply such masonry free of cost to the company.'

"In the first sentence the engineer usurps one of the most important functions of the contractor by asserting that 'the entire process will be under the control of the engineer'; and in the next sentence he seeks to escape the responsibility that morally and legally falls upon the shoulders of any one who assumes entire control of any method or process of construction. We have here an excellent example of the lax ideas that prevail as to what constitutes a free contractor and a servant. A contractor cannot legally be made both. If it is desired to hold the contractor to a removal of all rock shattered beyond the neat lines, then the engineer must carefully avoid acting as a master or 'boss' in directing just how the drilling and blasting shall be done. If, on the other hand, the engineer believes that he, himself, is a more competent blaster than any contractor is likely to be, let him manfully assume the responsibility for his own work; and he may as well assume it, for he cannot legally escape it in case of a law suit.

"The fact is that if the engineer does really possess an intimate knowledge of the proper methods of doing work, he usually is specific and not vague. He does not hide behind such generalities as are contained in the first sentence in the clause under discussion, but he says: 'Such and such a kind of explosive shall be used, and so and so many pounds of the explosive shall be the maximum charge per foot of drill hole, and no drill hole shall extend more than so and so many inches beyond the neat lines of the excavation, and drill holes shall be spaced so and so.' Such a specification shows at least that a study of the problem has been made by the engineer, and that he is prepared to stand by something definite.

"On the other hand, if the engineer cannot define what shall be done, for one reason or another, he had better take one of two courses: (1) Leaving the means and methods entirely to the contractor who is held strictly responsible for certain results; or (2) assuming entire charge of means and methods and specifically releasing the contractor from responsibility for results. Any attempt to follow both these courses is obviously unjust, and, what is equally to the point, will be upheld by no court.

"We have assumed, up to this point, that the contractor has no redress, but to any one familiar with the law of contracts, it is well known that an unreasonable interpretation of such clause as the one under discussion will render the employers of the engineer liable for damages; for, carrying the clause to an extreme, it would be possible for the engineer to compel practical abandonment of the work during the summer months and the use of doubly large forces during the winter months, a procedure which would ruin almost any contractor. Yet this procedure would be literally in accord with the wording of the clause which empowers an engineer to designate the time and place of attack and the size of the working force. No court will uphold a contract under which one man, at his option, may ruin another. The extent to which an engineer may legally direct the forces of a contractor will depend upon the reasonableness of the engineer's rulings. To prove or disprove the reasonableness of any ruling is a matter of evidence as to the facts and of expert evidence as to common practice. The cost of a law suit and doubt as to the outcome have deterred many a contractor from bringing suit; but the fact remains that, whenever an engineer ceases to be fair and reasonable in his interpretation of such clauses as the one under discussion, he runs the risk of forcing his employers to defend a law suit which will be expensive to them no matter what the final decision may be."

The following quotations are taken from a very interesting paper by W. F. Dennis, entitled "Uniformity of Requirements and Clearness of Specifications in Agreements for the Graduation of Railroads," to be read at a meeting of the American Society of Civil Engineers to be held March 6, 1907, and printed in the January, 1907, Proceedings of that Society, page 39 *et seq.*

" Agreements generally contain amplified stipulations that construction must be maintained by the contractor until the final acceptance by the engineer. This seems fair enough on its face, but the customary wording does not make equitable distinctions. It is easy enough to see that if the contractor, in such an act as transporting material to the work, suffers loss or damage of that material before it is put into the structure, the company has equitably nothing to do with the damage.

" Further, it is not unreasonable that a structure, such as a building, completed in advance of other work, all subject to acceptance at one time, should be insured by the contractor. The question becomes somewhat involved in the instance of, say, trestle-work which has been finally completed, in the event of destruction from a cause, not the fault of the contractor, before acceptance of the work as a whole; for railroad embankments washed away by water; for the destruction of masonry already laid according to specifications. If the contractor places the material where he is directed, no stretch of imagination could make it fair for him to be responsible for destruction by the elements when he has no control over the selection of the location or plan.

" As illustrative of the way in which equities are destroyed by such clauses, the writer recalls a case where a retaining wall which was too light fell down when the embankment was placed against it. The wall was rebuilt, payment for it denied, and the contractor sued. He established the fact that the wall fell because of improper design, and that the workmanship was according to contract. He lost on the ground that his contract was not only to build, but to maintain until acceptance, and his remedy would have been to have notified the engineer that the design was insufficient and to have made formal protest to building it.

" The writer recalls a personal experience in building a 30-ft. arch. This arch was built on a cemented gravel foundation which was perfectly satisfactory to the engineer and would have been all right ninety-nine times out of a hundred. The side walls and four cross walls were carried well down, and the bottom was paved with heavy stone on edge, well laid. The whole work was built under continuous inspection, and the destruction hereafter referred to revealed no fault of workmanship or material.

" This arch was accepted on a Friday. In the meantime the fill had been completed for part of its width over the arch, damming the small valley except for the arch opening of about 25 by 30 ft. On the following Tuesday, a cloudburst occurred, and the arch ran full and discharged as a pipe. The paving was dug out by the current, then the gravel was eroded, the side-walls fell in, and the disrupted structure was spread over three acres of ground.

" The first question asked by the management was whether or not the contractor was responsible under the 'insurance clauses.' This was disposed of by the technicality that the arch

had actually been accepted a few days before. Suppose the accepting engineer had been delayed on Friday and calculated to get there on Tuesday, instead; then a strictly technical construction of the agreement would have involved the contractor in replacing 3 000 yd. of masonry at his own expense. What had the contractor done, or not done, that could have made any real change in the equity of his position?

"According to the teaching of the case first cited, the contractor's legal duty was to have formally notified the company of what was not a fact, that the foundation was bad, and to have refused to build on the accepted foundation, except under protest. It seems to the writer that the simplest investigation of how unfairly these clauses can work out is amply sufficient to show the necessity of eliminating most of them and very carefully restricting the others.

. . . .

"Contractor to do the work where and when the engineer shall direct, whether the procedure is, or is not, a reasonable one in economical organization, and whether or not the procedure is fair.

"Where the company is in default from any cause, the expense shall be borne by the contractor, his relief is in extension of time, provided he gives notice and the engineer considers the point well taken.

"The contractor shall equip his work with such forces and appliances as the engineer shall direct. In case he does not, the company holds the right to employ the force and charge the expense; to annul the contract in whole or in part; to seize the contractor's plant; and to withhold any unpaid sums of money which may then be due. The contractor's employees are subject to discharge by order of the engineer. A reservation of 10 per cent. is withheld from the contractor's payments in addition to withholding, by custom, another part at the discretion of the subordinate engineer. The company, of its own motion, without default on the part of the contractor, holds the right to terminate the contract at any time, to suspend the work, to hold the contractor to resume, with stipulated denial of the contractor's right, not alone to damage, but even for recovery of expense. The contractor must obey all orders of the engineer and accept his determination as final, at a time when the engineer holds the relation of an employee and agent of the company; the contractor knowing at times that the engineer has no detailed knowledge of the work, and that the information which he certifies as his final judgment is, in fact, the work of an assistant, with whom he may not be even personally acquainted.

"Requirement that the company shall have the right to save itself in case of claims against the contractors; to make an *ex parte* examination, to settle the controversy and charge the contractor with the award and such expense as the company shall set, without consultation with the contractor, and without his acceptance. Requirement that the contractor shall exhibit complete receipts, showing that all accounts have been paid.

Requirement that the contractor shall save the company harmless from every matter growing out of the construction.

"Requirement that, before the contractor can get final payment for matters not in dispute, he shall accept the engineer's estimate as a total and release each and every matter and sign in full settlement, with a more drastic wording in some contracts; that the contractor shall have accepted the final, as handed out by the engineer, before the company shall have incurred any indebtedness to the contractor.

"Requirement that, after the contractor shall have done work which is satisfactory to the inspector appointed for it, the work may still be condemned and required to be done over.

"The stipulation in favor of the contractor is, that he shall have the right to accept without protest the sum of money the engineer shall say is due him.

"It is safe to say that in no other business relation between men are such one-sided agreements customary; in no other relation is a man conceived to be clothed, by reason of a written instrument, in a mantle of infallibility, as is the engineer in customary railroad contracts. In political matters, some thinkers hold that an intelligent despot can give the most efficient government; so, in the case of the engineer, granting an untrammeled, industrious and able man, subjecting the contract to his exclusive decision may work out as the best arrangement all around. As far as the writer's observation goes, the average and general result is good, without much genuine offset; but every now and then there is an instance of gross tyranny and outrageous wrong under these powers. The delays, safeguards and forms appropriate for a peaceful civilization would paralyze an active army. Railroad contract work requires somewhat of the army's autocratic directness of control; but the control should be within well-defined and reasonable lines.

"The objection in a practical sense, however, comes, not so much from arbitrary or unfair use of the engineer's power, but from his carrying out, or being forced into carrying out, requirements which are too broad or are unreasonable, which he may have thoughtlessly included in his agreement, put there from mere copying of precedent, or at the suggestion of a legal department which considers only its side of the case. Ordinarily, these clauses are unnecessary. In spite of them, most engineers have to and do make fair adjustments, and settlement for the majority of work goes through with mutual satisfaction. With these clauses too strongly drawn, the engineer, in spite of a personal desire to be fair, may be forced by his company into an opposite policy, in accordance with the stipulations of the contract. In no class of cases is there greater real damage done than when organized work is suspended or stopped.

"In the old days, when contractors' equipment was carts, scrapers and stock, the suspension of work was a serious blow. At the present time the organization and plant for work is multiplied many times more than the requirements of twenty years ago. The expense, effort and time sunk in organizing,

very often with special plant, has only a partial relation to the work which may be performed at a particular date. It is a general expense to prorate over all of it. Any suspension or stoppage cuts off the profitable part of the work, and where no compensation is made for the stoppage, the contractor is in effect robbed, whether it be by agreement or not, presuming that the contract was profitable in itself.

"It must be further considered that the contractor, in making agreement for a given piece of work, has taken the risk, and if it can be shown that the uncompleted work would have been profitable, upon suspension of this work, he is legally and fairly entitled to that profit, subject to such offset as would be made by an earlier release of services. The no-damage clause offsets this or any other claim.

"As the writer understands the obligation of contracts, in matters of measurement, classification, workmanship, meaning and application of specifications, and the like, which have to be decided by an expert, and for which the engineer is nominated by agreement as such an expert, his finding and decision will be held final in the absence of fraud. All other matters are at least open to court review. Therefore, a clear, fair contract interpreted by the engineer has a better chance to be upheld in its final than one which is unfair and extravagant in its stipulations in favor of the company. The time has about come for the companies to be willing to assume the risk of their own acts and plans, and not to saddle these risks further upon contractors.

"In conclusion, the writer would say that the main thought in this whole discussion is: That a contractor and a company enter into an agreement for mutual benefit. Every matter not clear, subject to whim and opinion in its working out, unfair in its intent, or in the nature of a 'strangle hold,' is unfair to one side and reacts upon the other, and that the business of both parties is best served by a fair agreement."

Specifications.

The troubles arising on account of specifications are due about equally to the text as written and to the interpretation of the text when written.

Engineering is an exact science, and a specification must be explicit and cannot use the word *about;* and the main point in the interpretation is how much variation from the exact figures given can be allowed. We cannot get perfection; it is useless to try to get that in this world, and as its substitute, we must get as close as possible, and as practicable. It is a question of practicability *versus* perfection, and the man who has the good judgment to get the best practicable is the successful man. As was said by one of Massachusetts' most prominent men at the inaugural of a president of one of Massachusetts' most famous institutions: "He has learned to do justice to opponents, has

become convinced that it is better to get the *best possible* than to prate idly about an *impossible perfection;* find fault perpetually and get nothing."

These words are a whole sermon to me, and one we would always preach (did we preach) to young engineers. You engineers know so much more than we contractors that you often assume we know some little you know. You put common words into a specification, which words have a common meaning to us, and then when we get to work, you bring out your interpretation of those common words.

For instance, "coarse, sharp sand shall be used." Does this mean that 27 per cent. of this sand shall pass a 200 sieve, or that 86 per cent. shall pass a 27 sieve? We never did nor do we ever hope to know. If size of sand is to be tested by a sieve test, specification should so state.

"*Cement* shall be of a well-established brand, shall be subject to inspection and rigorous tests of such character as engineer shall determine." Does this mean, in the entire absence of any detailed chemical composition, that we shall furnish cement having abnormal proportions of sulphuric acid, magnesium and of lime, either high or low?

"A pile shall be at least 6 in. at tip, and *not less than* 30 ft. long." Does this mean that the minimum of 6 in. for tip and 30 ft. for length shall be allowed to be used, and as much larger tips or longer length as the engineer may require, or does it mean no pile can be required driven with a larger tip than 6 in. and a longer length than 30 ft?

"The stone used in the work shall be from one quarry, shall show no streaks or sap or other imperfections and shall be uniform in color." Does this mean that each single stone shall show no sap or streaks and shall be uniform in color, or does it mean that all the stone in the work shall be of the same color, with no streaks or sap?

Timber attached to masonry. "The contractor will be required to embed in or attach to the masonry sills and bearing timbers and such other timber as may be required."

Definition of timber, according to dictionary: "Wood fit for building; a piece of wood squared or sawed."

Can you conceive of a frame, with bolts and bearings, fitted for gates, for door frames, window frames, and I don't know but mosquito frames will come later, being considered as *timber*, to be set at a given price per thousand?

Should not specifications be explicit on these points, that a contractor can know on just what he is bidding?

The engineer should know what he wants when he writes his specification, and should state it, and not come around after the contract is signed, all material contracted for, and then bring out some special tests wanted, some wire factory work, or some special interpretations which the contractor never heard of.

Very much trouble comes from masonry inspection, the quality of the cutting, the size of the joints, plug holes, etc.

Regarding the matter of masonry joints, I want to say a word. Early in our engineering days, we were talking with a stone man about good joints, and he told this incident:

He cut some large stone for a government job for engine beds, and the specifications called for pean hammered beds and joints. He made them, work was accepted and built. In a very short time, under the vibrations of the engines, the joints parted. The stones were taken out, " plugged " good and hard, and put back, and stood the vibration without trouble.

At Portland, Me., is another government job, a small arch, where the joint next the skew back is about a $\frac{1}{4}$ in. The whole length of the arch stone has split off, owing to thin joint.

To-day there is another arch, the longest railroad span in the country, standing without trouble under a terrific load, with mortar joints which will average 2 in. thick.

We give these facts to show the trouble which has come to fine small joints, and also to show how much a large joint, built solid, can stand. But stone is hard and tough, and the men who cut it are equally hard and tough, so that much trouble comes to work where the stones are all "*specials*," and some one is plugged too hard, cut slack or is off-color, and the whole job has to shut down to wait for a new stone from a quarry a hundred miles away.

We can't ask you to discharge your inspectors and take everything that comes, but we can and do ask for reasonable inspection, for a consideration of the means through which material is obtained and manufactured; that when you want a monument you ought to have it as good and true as man can make it; but when work goes out of sight, under ground or under the sea, a pea-green stone is as good as cadet gray, and a $\frac{7}{8}$-in. joint as good as a $\frac{3}{8}$-in.

Generally speaking, we do not cut or furnish the stone, and the loss of a condemned stone doesn't fall on us, but the spirit of getting a " pound of flesh " is what makes the trouble, and extends from the contractor, through the superintendent, foreman, masons and even to the water boy.

If a contractor, bidding on public works to-day, ever tries to figure on all the chances which may come up, he never will get any contracts. He has to run the risk, to trust that some things will come his way, enough to balance the things that go against him. He doesn't want to be always kicking, making claims for extras, for small things, in the hope that the engineer will give him the benefit in doubtful cases, and such advantages as the work may offer, enough to offset his little extras. But when he doesn't get any of these benefits, especially if he feels that the engineer is willfully withholding them, is compelling him to do the work to the exact letter of the specifications, where such work is of no value to any one, when he is, in the common term of the profession, " getting roasted," then comes trouble, claims for extras, kicks and general eruptions.

Do you know what the lack of a square deal means? That the other fellow denied this now great American right has it in his heart to " get even " with the man who denies it to him, and it takes a good Christian and a square man to curb that impulse.

To give and to take, to do justice on the one hand, and good, honest work on the other, and then settle the differences, man to man. Then lawyers will go out of our lives, courts be left for the Boston Elevated cases, and then will come the day of good-fellowship and regard which should exist between the creators and makers of this modern world, the engineers and contractors.

The following quotations are taken from a personal letter of Mr. Seth Perkins, civil and contracting engineer, of Boston:

" The traditional and proper function of an engineer as related to contracts is to act as an arbitrator between two parties to a contract, and as all contracts are presumed to be conceived in fairness every impulse of an engineer should be to measure the fair rights of each party in having the work properly carried out.

" Theoretically, works are designed and specifications and plans are drawn to give true and graphic exhibits for the purpose of obtaining competitive bids.

" Practically, engineering is not an exact science, nor can it be on account of the many uncertainties bound to exist, which only develop into certainties as the work progresses. The engineer animated by an idea of fairness could draw his specifications in such a way as to definitely specify known factors, and provide for the unforeseen conditions in a way which would insure justice to both parties. But this never will be done while engineers work from fixed clauses probably dictated by a mind trained in legal thought and without the elasticity which is the outgrowth of engineering experience. I feel in many ways that the engineering profession has been made subservient to the legal, and I think to

its detriment. There is no profession in which the training tends so much to analysis and by force to synthesis. Then why should we allow the legal profession to dictate arbitrary clauses in specifications which are in conflict with our judgment and bound to place us in a false light? The only use to which I have been able to put the legal profession is to unravel snarls of their own making, and then they had to call for expert knowledge where the knots were too tightly drawn. I suppose the burden of your argument will be objections to the arbitrary clauses in contracts and I think they should be attacked. For when controversy arises, as is often the case, where unforeseen conditions come up that have not been made the subject of particular specifications, the usual result is to fall back on general clauses which are generally arbitrary, and if the controversy assumes the proportion of litigation the interpretation of these clauses is left to a Court having no training which would entitle him to judge what was the original intent of the engineer responsible for the specifications or the spirit they intended to convey."

DISCUSSION.

Mr. H. H. Carter (*by letter*). — Two or three years ago I took considerable interest in the matter of Mr. Rollins's paper. I appeared before a legislative committee for two successive years endeavoring to have a law passed making it obligatory for the commonwealth, cities and towns to introduce into their contracts an arbitration clause instead of the present clause making the engineer sole judge of everything.

The matter has largely gone out of my mind at the present time. I will, however, look through a Transit Commission contract and mention a few points.

First. Contractors object to the present clause making the engineer referee to decide all questions relative to the *fulfillment* of the contract, and that his estimates and decisions shall be final and conclusive. It seems to me while the engineer is properly made the judge as to the fitness of materials, he certainly should not be referee to decide all questions relative to the *fulfillment* of the contract, and that questions of that sort should be decided by three parties, one to be appointed by the commission, one by the contractor, and these two to select a third. This provision you will find in force in the contracts drawn up by the Master Builders' Association.

Second. Contractors object to the clause stating that "if delay occurs on the part of the commission in furnishing the material, or if the contractor is delayed by other cause which is not his fault, the contractor shall have no damages on that account," etc. This is manifestly unfair.

Third. Some contracts contain a provision that in figuring the cost of extra work the contractor shall not be allowed to have superintendence, liability insurance, etc., figured in. As these are matters which all enter into the expense of the work, they should be taken into account in figuring the expense of extra work. Liability insurance in some instances amounts to 9 per cent. of the pay roll, and there is no reason to leave it out as an item of expense in contract work.

Fourth. I think the time has now come when engineers should entirely revise the present form of contract and specifications and draw them up in a spirit of fairness to both contracting parties. The present form of contract arises from one engineer after another, assisted from time to time by a petty lawyer, endeavoring to alter the previous form of contract and introduce some ironclad clause, still further tying up the contractor body and soul and throwing on him the risk and expense of work which justly the other party to the contract should bear.

Fifth. All clauses requiring the contractor to do certain work at his own expense, "*unless otherwise directed*," should be done away with. Such clauses throw doubt on the good faith of the engineer and leave the contractor in doubt as to how he should make his figures, and also give him the idea that some other favored contractor knows in advance how the engineer will direct.

Sixth. All clauses should be done away with giving the right to the engineer to deprive the contractor of compensation for necessary work done under the contract. For instance, a recent sewer contract contains provision for 5-inch tongued and grooved sheeting driven below grade. The engineer has the right to order it taken out on the completion of the work if he so elects in which case the contractor receives no compensation for furnishing and driving it. If it is left in, however, he receives $70 per thousand feet board measure. This item alone on the particular contract referred to left the contractor in doubt as to whether or not he would receive any compensation for $40 000 worth of prescribed work. This is the kind of clause, when it is shown up in court or brought before the public, that throws suspicion on contractor and engineer alike. The idea that $40 000 worth of work *done* by the contractor may be paid for or not as the engineer decides, by a stroke of the pen, is one that sets ordinary people to thinking and does much to keep alive the continued talk of graft in connection with contracts.

Seventh. All clauses requiring the contractor to do work at

his own expense when such work is not contemplated by the plans and specifications should be altered, and if such unexpected work is necessary, the clause should read that such work is to be done at the expense of the other party to the contract.

I must say that once in a while it is a satisfaction to see the engineer "hoisted with his own petard." The recent trials of an engineer for fraud in connection with a large filtration plant were based on a lot of fool clauses in the specifications which an alleged set of reformers thought should be interpreted to ruin the contractor. For instance, the borings for a filter gallery covering a large territory showed that the material was all clay and gravel. The engineer unthinkingly put in the clause relating to excavation that the contractor was to excavate to the prescribed line for the concrete foundation, and that if any soft material was encountered below this line it was to be excavated and refilled with concrete at the contractor's expense. The contractor gave a lump sum bid on this work, and as the borings showed hard ground, he naturally made no allowance for excavation and refilling with concrete below grade. After the work was completed, an area of over an acre was discovered which contained muck running as much as 15 ft. below grade. This meant about $200 000 worth of work to be done by the contractor at his own expense. He naturally objected to doing this work without compensation, and had a hearing before the proper authorities, who decided that in view of the fact that such a large amount of extra work was not contemplated by the original specifications, that he should not be obliged to fill the excavation with concrete. After this decision the Philadelphia Goo Goos, or some similar organization of broad-minded individuals, thought that there must be fraud, and the engineer was arrested for abetting it. The trial naturally resulted in the acquittal of the engineer. It is safe, however, to assume he will rewrite the clause about refilling below grade and put it in such terms that in future he won't run the risk of going to jail because he recommends that the contractor shall not be driven to bankruptcy by the enforcement of clauses which were written to cover entirely different conditions.

Mr. Rollins has put the whole matter of these contracts and specifications in a nutshell when he uses the term "a square deal."

Unfortunately, the training which some engineers go through, unless they are big broad-gage men, seems to shrink them up into the class that looks on the cent as the ordinary man looks on the dollar.

When engineers realize that pettiness and meanness and the desire to be unfair to other people, as exemplified by the way they write specifications and contracts, only reacts on themselves and gives broad-minded people an idea that they are a small class of people, to be paid and considered accordingly, — when they realize this, then perhaps we shall see a fair set of specifications.

Mr. Charles G. Craib. — If I were a lawyer and were conducting a case, and you were the jury, after hearing Mr. Rollins I should say I would be very well satisfied to rest my case. He has presented the objections to the average contract and specifications in engineering works in a very able manner, and I don't expect to be able to add anything to what he has said along that line.

There is a fictitious value created every time you add a hardship to the parties that are going to perform any service, and it seems to me that that feature ought to be considered in connection with a matter of this kind. I haven't had a very large experience with engineers, but such as I have had has made me feel that professionally they stand at the head of all others; that they contribute more to our general welfare and to the general advancement of all of our interests than any other profession. Most of the good clothes we wear and the comforts we enjoy are sometimes said to be the direct result of education. I think they are largely the result of the work of the engineer. So that it is without prejudice against the engineer that I make any remarks.

Before going into details on the subject of contracts, and to show how this clause that has been referred to in the specifications, giving so much power to the engineers, works to the detriment of the contractor in an unfair manner, I will speak of the contract that I had in a city not far from Boston. We had a trench, not very deep, but it seemed to me that you'd stand about as much chance to put a pump on a raft in Boston harbor and try to pump the water down as to pump that trench. After opening a large section of it, it was necessary to have a large number of pumps, and it was thought best to move those pumps on Sunday. The next Saturday night at 12 o'clock we began making the change, so that the work would be in a condition for digging the next Monday morning. But under this general clause in the specifications the engineer took it upon himself to come out Sunday morning in the midst of the operations and stop the work simply because it was being done on

Sunday. There is no law I know of, as this was so far removed from dwellings as not to be a nuisance to any person, under which he could do that except by placing a very broad construction, from his point of view, on that clause in the specifications giving him the power to regulate the contractor's work. There was a case where it worked very much to the disadvantage of the contractor. Another case occurs to me, in a town which has since become a city, in which the pumping was stopped in the middle of the day on Sunday by the engineer because there was an objection made by people who attended the church close by. I shouldn't have thought very much of that if I hadn't known that a number of the people who made the complaint were interested with Jernigan in trying to extract gold from sea water and to sell stock for that undertaking. I thought that their religious scruples were rather far-fetched in my case, but of course they had to act through the engineer, which they did. In another case I contracted to lay a 20-in. pipe in a trench, and the engineer specified how the joints should be made. A string of jute was to be inserted in each joint. The pipe was furnished under another contract by the town, and I think that out of 550 ft. we found four pieces that would go together without chipping. Still the engineer insisted that we should chip off enough to get the jute in, because the contract specifications required that we should do that. Those little things form the reason why contractors and engineers are at odds at times. It is not the general specifications. I have read through carefully during the past few days several sets of specifications, and I cannot find a word anywhere that I'd be willing to cut out, looking at it from the point of view of the citizen. The speaker was superintendent of a large sewer contract, where the contractor would not do certain things that were necessary for the success of the enterprise because of the expense; when failure seemed inevitable, the engineer took charge of the work, with the result that the work was put on a good financial basis, turned over to the contractor, was continued by him to completion, very much to the satisfaction of all parties interested. The one trouble is that we don't have engineers to deal with such as are now at the head of the departments of our public works in all cases. If we had, there would be no trouble. But to explain my meaning, I might tell you what happened in the case of a young engineer I heard of. He got his friend to bid on a contract, and he made all kinds of absurd conditions and inserted them into the specifications, and said to his friend, " Why, that is all right. I just want to

make a good contract, so that they will know that I have attended to my duty. There will be no trouble about the work because I don't intend to enforce any of these conditions." His friend took the contract and the young engineer died. Another man came along and enforced the conditions. So you see if we only knew that the man who draws the contract is the man who is going to construe it, and that he is a man like our presiding officer to-night, there would be no trouble. But it isn't always so. The general objection to general specifications is not that it is not wise to have a good strong set of specifications, so that the engineer can have control of the work, but it is that some engineers take advantage of that and neglect to give the contractor's side of the question proper consideration. At this time, when so many engineers have taken up the contracting business, some arrangement could be made by which a general form of specifications might be recommended that would be more in a spirit of fairness to the contractor and in justice to both parties to a contract.

Mr. Charles R. Gow. — I believe Mr. Rollins is to be commended for the introduction of this somewhat novel discussion, in which nearly all of us are interested on one side or the other.

Possibly his remarks and arguments may appeal to many of you as engineers in a way that will be beneficial to others of us in the future as contractors.

As pointed out by him, there has been a combination of engineering and legal skill working together for many years past in an endeavor to evolve certain standard types of specifications and contracts designed with a view of securely fixing the responsibility for all uncertainties and unforeseen future contingencies upon the party who has no voice in the framing of the contract, namely, the contractor. That this united effort to reach perfection in the matter has not been entirely successful is evidenced by the number of cases which still require the final adjudication of the courts. That it has been for the most part successful, however, can be testified to by many of us, who have paid dearly, from time to time, for the privilege of learning this fact.

It is probably no exaggeration to say that this disposition to, in a sense, take advantage of the contractor by the shrewd wording of the text and skillful evasion of responsibility has been the cause of more dishonesty on the part of contractors than any other single reason.

How often we have heard our engineer friends condemn, with righteous indignation, the habit of the contractor who studies the contract and specification for some loophole or omission through which he may legitimately claim additional compensation or relief from onerous requirements. How often also have we seen the same engineer, when he discovers that he has failed to foresee and provide for some contingency which has arisen, take refuge behind some blanket clause, which never contemplated this particular contingency when it was written. Are not the two traits identical? The contractor seeks to safeguard his pocketbook and the engineer his reputation as a far-seeing and shrewd official.

I agree with Mr. Rollins that the greatest absurdity that exists in present-day contracts, from the standpoint of fair play, is the clause making the engineer sole arbitrator in cases of dispute.

It is inconceivable to me that any man who must of necessity be a party to the dispute, and having made up his mind in advance, could or should desire to exercise the judicial function of a referee in deciding whether he or the other party is right. It is a fact that this clause is accepted by 99 per cent. of the practicing engineers as a mere subterfuge to escape the consequences of arbitration and to bind the contractor to abide by the engineer's decision, regardless of the merits of the controversy.

I have never known but one engineer in my experience who admitted that this clause could, in any way, operate in the contractor's favor. Fortunately for the contractor, the courts have placed some limitations upon the extent to which this clause may be applied.

Not only are we obliged to accept the engineer as referee, but in addition must agree that our methods, men and materials will be acceptable to him, and that he shall finally decide whether or not we are entitled to any compensation, and if so, what amount. Can you not imagine that under these conditions the personality of the engineer will enter largely into our estimates of costs? Some engineers we do not care to work for under any circumstances. Some require that we add a large percentage to our figures to provide for their close and arbitrary dealings and interpretations, while still others are known to us as fair and liberal-minded men with whom we feel justified in taking chances and have confidence in obtaining a square deal. Some engineers accept a contract in the same spirit that they

would the gospel, as something inviolate, any deviation from the letter of which would condemn them to perdition for heresy, while others are willing to look upon it as a purely business agreement, to be carried out for the best mutual advantage of the two parties. Is it difficult to guess which engineer will obtain the lowest prices on his work?

As contractors, we naturally expect to assume certain risks. We admit that we must be expected to gamble on the labor conditions and prices, upon the fluctuation in cost of materials, upon the effect of weather changes, upon errors of judgment in making our estimates, upon freight delays, upon the possibility of serious accidents to persons or property and other features of like nature; but worst of all is the gamble we take on the uncertainties imposed upon us by the contracts and specifications, when we assume responsibility for all delays caused us by the owner, for all errors or inaccuracies in studies or plans, for all oversights on the part of the engineer, and not infrequently for the correctness of the engineer's lines and grades.

Added to all this is the uncertainty of the disposition of the particular engineer and inspector assigned to supervise our work and upon whom we must depend for the interpretations of the very elastic wording of the specification.

As to the specifying by the engineer of the detailed methods of operations, my opinion is entirely in accord with that of Mr. Rollins. I fully believe any unbiased individual will admit that the average contractor is a far better judge of the proper methods to obtain desired results than is the average engineer, yet a majority of the engineers seem impressed with the idea that their technical knowledge entitles them to the privilege of directing the contractor in the management of the details of his business.

As an example, I was once consulted by a prominent engineer as to the proper procedure in a matter of which this engineer had no previous experience. He requested my opinion on account of certain successes I had made in the class of work under discussion. Subsequently he embodied in his specification the general method outlined by me, but in addition also his own conception of the detailed manner of carrying on the work, a conception which, by the way, was erroneous. It so happened that I was the successful bidder, and much to my surprise and disgust was obliged to follow out his ideas in spite of my protest, with extremely unsatisfactory results both to the engineer and myself.

Another habit which is growing among contract writers is that of specifying prices for certain items. While I can see no good reason for usurping this one of the few contractors' privileges, there would be no serious objection to this habit if the engineer would commit himself definitely as to the probable quantity involved. I have never known an engineer to specify an excessive price for any of these items, and usually the contractor prays that there may be no work of this classification if he must accept the price set.

On a certain contract executed by our firm, a price of $13 per thousand was stipulated for sheeting left in place. No estimate was given of the probable quantity to be used, but it seemed likely that the amount would be inconsiderable. On the contrary, there were 150 000 board ft. so left in place, costing us for the lumber alone $22 per thousand, and representing a loss to us of $1 350 outside the labor cost. A protest to the engineer against this arbitrary allowance on so large an amount was met by the argument that we should have taken it into account in making up our bid; but how could it be considered in the bid when the amount to be used was absolutely unknown? We were then reminded by him that we should not have bid on the work if we did not like the specification. This argument is in line with that of the railroad official who tells you that you do not have to ride on the cars if you do not like the service. You can get an automobile or walk.

There is a very general tendency among engineers, and I can refer back to the time when as an engineer I did the same thing, to make certain requirements simply because they are called for by the specification, and regardless of whether or not they are necessary in the sense that the specification intended. Undoubtedly every clause contained in a specification had originally some reason, either good or bad, for its existence. Too often, however, many of these clauses are enforced against the contractor without any reason.

I was at one time prevented from using second-hand lumber in foundation platform, not that the quality of the lumber was in question, not that it would not fulfill the function as well as new lumber, but merely, as the engineer explained, because the price stipulated for this item contemplated the use of new lumber.

On another occasion a contract for a certain state commission called for the use of several thousand barrels of cement

of a brand acceptable to the engineer. A canvass of prices obtained from the cement dealers showed one brand to be quoted 30 cents less per barrel than the others. Upon submitting the matter to the engineer I was informed that this brand would not be accepted, and the higher price was therefore paid. A few weeks later I learned that this same engineer had contracted for a large order of the cheaper cement for use on day work being done by the same commission after bids for the work had been rejected as being too high. The same specification for cement had previously been used by the bidders on this work as applied to my work. On the same contract I was required by the engineer to suspend work until heating arrangements satisfactory to him were installed, while a personal visit by me nearly a month later to the day work referred to showed absolutely no attempt at heating or heating apparatus.

All these things illustrate the fact so long realized by contractors that the strict wording of contracts, together with the extraordinary powers delegated by us to the engineer, often serves as an inducement to him to exact everything from us that he can possibly obtain, regardless of necessity, so long as no additional expense is entailed to his employer. As soon as the expense becomes a matter in which he is personally interested, his views often experience a strange and violent change.

Still another matter which oftentimes causes unnecessary annoyance and hardship to the contractor is the tendency of engineers to retain all of the contractor's money that their consciences will allow. The general rule appears to be, "In cases of doubt, hold back enough."

First we are required to furnish a bond of from 20 to 50 per cent. of the amount of the contract. Next a reserve is retained of from 15 to 25 per cent. of our monthly estimate. Before the allowed estimate becomes payable to the contractor, from one to three weeks' additional work has been completed and forms an additional security to the owner.

It would appear to an ordinary individual that the above items would amply secure the owner against any breach of contract on our part. The average engineer, however, takes a different view of the matter, his idea of an approximate estimate being one that is well on the side of safety, for why should the contractor complain when he knows that he is to receive the remainder upon the completion of his contract some months hence? Meanwhile the contractor must pay 100 per cent. of

his pay roll every Saturday night, and if his material bills remain unpaid after thirty days, the various credit agencies are investigating his financial condition.

If engineers were obliged to pay 6 per cent. interest on all reserves, it is safe to assume that they would soon experience a change of heart.

Practically all of the evils referred to are attributable to the blanket clauses contained in our contracts. There is undoubtedly a necessity for the insertion of certain clauses of a general nature which cover certain specific classes of work. These are understood in advance by the contractor, are accepted in their general sense and provided for in his estimates. It would seem, however, that the English language is sufficient to fully cover and clearly explain every individual thing that the contract is intended to cover, the general method of procedure expected and the prices for payment of same, without resorting to vague and indefinite blanket clauses which mean nothing to us when figuring the job, but which may mean thousands of dollars before the work is finished. The presence of such clauses in a contract may be accepted as a confession on the part of the engineer that he does not know in advance what he may or may not want the contract to cover.

In conclusion I would suggest that when engineers, as a body, concede that the business of contracting is a legitimate and honorable profession, requiring a marked degree of ability, knowledge and experience; when they are ready to coöperate with and not antagonize the contractor who is trying to fulfill the requirements under trying conditions; when they recognize the fact that they have no right to expect something for nothing, and when they are willing to deal with the contractor in the same spirit of fairness and charity that they would with their grocer or other dealer at home, then, and not until then, can we expect perfect harmony and mutual understanding.

So long as they insist (as Mr. Rollins has put it) upon "their pound of flesh," just so long may they expect we will give them an interesting time in getting it.

Mr. E. S. Dorr. — If the contractors have nothing more to say, I think something might be said on the other side. Mr. Rollins has given us an excellent disquisition on what a contract should be, how it should be drawn for a fair-minded contractor. He has not told us what sort of contract we should draw when we have to deal with an unfair-minded contractor. It should be remembered that when the contract is being drawn the engi-

neer does not know what kind of contractor is going to get the job. He has got to assume that he will not be a man who will meet him in this fair spirit, and therefore he must trust to the contract, and he draws one that will give him the advantage. That is to say, if a controversy is going to ensue, and the very practical question comes up as to who is going to have the whip hand in the contest, of course the engineer will try to secure it for himself. And I think in that consideration is to be found the answer to the question why these clauses are kept in. Of course, if the engineer be a fair-minded man, he is not obliged to do an injustice on account of having the ability to do it. But he is enabled by the presence of these clauses to do justice, because, having the whip hand, his hand cannot be forced by the contractor. I think that is the only justification for the presence of these clauses which our friends have been inveighing against. If all contractors were fair-minded and honorable men, I would agree with Mr. Rollins and the other speakers that these clauses would have been very much better left out.

Mr. L. S. Cowles. — I think some of the unpleasantness that arises at times after contracts have been signed might have been avoided if, in looking over the bids, due consideration were given the contractor. In looking over bids, a corporation or an individual naturally will select the lowest responsible bidder. But perhaps those bids have been sent in under a misapprehension, and this responsible bidder who is the lowest has made a mistake in making up his bid. In that case the engineer, before the contract is signed, should call the attention of the corporation he serves to the fact that he thinks there has been a mistake, and as a result the contractor is notified and is allowed to change his bid. Under those circumstances perhaps he would no longer remain the lowest bidder or would be given a chance to withdraw. In a case that I recall, a Boston contractor had neglected to include in his bid some 1 200 oak piles and the driving of the same, which was quite an item. The result was that his bid was the lowest by far, and on calling his attention to the fact that he must have made a mistake, he admitted that he had made up his bid on a Sunday evening when some folks came in to call and he hadn't got as far as those piles and so left them out. But he came out man fashion and said he would see the thing through at his own loss. He was released, however, and the next lowest bidder secured the contract. That, of course, was before the contract was signed. So in treating the contractor, as Mr.

Rollins has said, man-fashion, he was enabled to withdraw without pecuniary loss.

Mr. Edward S. Larned. — I do not speak at the present time from the standpoint of the engineer who is directing the work, nor from the standpoint of the contractor who is performing it. But I have been, in times past, in the position of the engineer directing the work, and I think some of the statements of the contracting engineers who have spoken this evening are worthy of very careful consideration. It is not so much the specific terms of the specification as it is who is going to interpret the same, and in my experience it has come to be largely a matter of personal equation, and if this was more generally impressed upon the minds of engineers and their clients they would see the full significance of it. I haven't a doubt that on some work the cost is enhanced from 10 to 15 per cent. by reason of the fact that certain engineers are going to direct it. Contractors know by previous experience that they must allow at least that much margin to cover the exacting requirements of the engineer directing the work. It is not that such engineers get, perhaps, a better quality of work, but it is because they are, in the minds of contractors, unreasonable in their requirements.

Another feature of engineering control which is of very great importance to the contractor is that of the function of the directing engineer or the inspector. Now on some work it has been found that inspectors who were intrusted with the passing upon the quality of materials and workmanship do not stop with that, but in their zeal and interest they go further. They attempt to direct the work. In other words, if the contractor is a man who is disposed to resist the dictation of that sort of an inspector, he may, under some conditions, claim that it is interference, and under the strict interpretation of the meaning of the act, the inspector is interfering. And in just so far as he does that he is doing the contractor a very great injustice. The contractor, on the other hand, realizes that it is policy for him to be reasonable, amiable and willing, and he oftentimes does things that he knows are causing him a very serious loss in the performance of the work. But he does it as a matter of policy. In my experience I have seen a very great change in just that feature of engineering work. I think there has been a distinct progress. Things are very much better now than in times past. Chief engineers have come to appreciate that they must look after their engineering assistants a little bit more

closely, and that is a feature I would like to call attention to. Oftentimes contractors are not so much afraid of the interpretation of the engineer who draws the specification, or the man who is really in charge of the work, as they are of the assistant who is put in control of the work. Oftentimes the chief engineer is far removed from the source of the trouble. He may be fifty miles or even much further away, and it takes a long time to bring in a question of arbitration. A contractor is reluctant to resort to that. He knows it is policy for him to conform in every way to the desires of the assistant in charge of the work, and naturally refrains from reporting to the chief engineer that he thinks things are being done that to him are an injustice. This is a very important feature. And in connection with that I have often seen the importance of having a more intimate association between the chief and his engineering assistants. It would be a very helpful thing if chief engineers could bring their assistants together at stated intervals and have an exchange of ideas, a sort of question-box proposition, and let the young engineers or inspectors, who are the men directly in charge of the work, bring up questions of doubt or in dispute so the chief may discuss and explain the same, and in this way educate and broaden the men intrusted with the carrying out of his ideas. There is no question that every young engineer needs broadening, and if he has found his experience on one work alone, it is to be presumed that it will be years before he will be able to take a specification and interpret it rationally. You will find a difference between the interpretations of engineers in different parts of the country. New York is one thing, Boston another, and the Middle West and the Far West another. Experienced contractors take these things into account when bidding on work. It is not that the quality of the work is better in one case than it is in the other. . . . Now as to the engineer's not knowing in advance who is to take the contract. I don't like to designate a claim of that sort as being somewhat lame, but I think it could be very justly termed so. In the advertisement, and in the contract itself, the engineer distinctly reserves to himself the right to award the contract to the contractor who will best serve the interests of the other party. If a contractor is notoriously dishonest or untrustworthy, even though he be able to furnish bonds, there is no reason why the engineer should award him that contract. He would simply be inviting trouble. He should exclude that man's bid. Why does any reputable contractor make a reputation for himself? That is his capital,

and if by so doing he can get contracts at a better price, he is entitled to them. There is no profit to an engineer or a corporation or an individual in having disreputable contractors do work. Trouble is bound to result, and nothing good can come out of it. The fact that contractors take chances in specifications is a well-known fact. I don't believe one contractor out of ten reads the specifications in advance of his bidding carefully. He inquires who is the engineer. I don't think that is overdrawn a bit. In the last few years I have served in the capacity of adviser to contractors, engineers and architects, and have figured some work with them, and it has been particularly interesting to me to find the attitude of contractors toward engineers. When I inquired of them if they knew specifically the features of the work they said, "No, we know the specifications call for concrete of certain proportions, rock excavation, earth excavation, piling, embankment, grading, etc.," but the particular requirements that mean cost are not so much referred to as is the question of who is to be the engineer. I think the significance of that is not to be overlooked, and if the engineer makes a reputation of being fair and practical in all matters of arbitration he will find in his following a class of contractors who will bid fair prices on his work and give him good quality and progress at all times.

In the matter of specifications covering the materials, I think there has been an advance in that in the last few years, and I refer more specifically to cement specifications. Four or five years ago there were something like two hundred cement specifications in force in this country. You can understand what the manufacturer was up against. It absolutely forbade a uniform product. A mill was in the habit of catering to certain interests, and in doing so they, of course, observed those specifications. But if they went outside they were immediately in difficulty. Now that, happily, is over. We have, in 1904, adopted by the American Society for Testing Materials and American Society of Civil Engineers, what is known as standard specifications for cement. That is practically the basis for all the leading specifications to-day, and that difficulty is overcome. If, as in the instance referred to by Mr. Gow, the engineer denies the contractor the privilege of buying a cement over 30 cents cheaper than any other brand, and reserves to himself the right to select that for his own use in similar work, the contractor has redress in his own hands: he can submit that cement to a test and if it meets the requirements, — and there must be some re-

quirement beside the personal will of the engineer,— if it meets the requirement, the contractor can use it in the work. The question of contractors protecting themselves by taking exception to certain features of the contract or plans is a very important one. It is about the only means a contractor has to protect himself in a case of doubt, and I don't believe the time will ever come when we shall have a different condition in that respect.

Specifications at best are general in describing work. Plans in many instances can only be general, and there may be many details to add. And if, upon the development of the work, conditions arise that result in very material change, and the engineer is disposed to confine himself to the most economical design originally suggested on the basis of assumed conditions, irrespective of the contractor's rights and interests, then the contractor must, for his own protection, formally and by letter, state his position. I know of successful contractors to-day who make a practice of doing that even where there is no occasion for doing so. It is a matter of policy with them. The moment they feel in doubt in the slightest degree about conditions or results, they write a letter to the engineer that puts him and them on record, and if it comes to a judicial adjudication of the case, they have established their case in advance and fortified themselves very materially. From the standpoint of the contractor it is a pretty good policy to follow. The question of the intent of specifications and plans is a very broad one. One might take exception to many variations we find in interpretations of that nature. And it all comes back to a question of personality. The reasonable engineer is as explicit as can be under the conditions, and in the enforcement of contracts he is still reasonable and still practical. And if he is all that, he is all the contractor can expect. One great trouble with many engineers is the fact that they are not practical. Their ideas are very good; their judgment as to results can't be challenged; but their judgment as to the method of getting those results is sometimes very open to question. If an engineer lends himself to controlling the contractor in his methods, he makes a very great mistake, in my judgment. He would better let the contractor take his own way, when possible, and then pass upon the results.

The low bidder in competitive work frequently names ruinous prices if the contract be rigidly enforced and any unexpected difficulty arises; this means, as a rule, only trouble for

everybody concerned and demands from the engineer the utmost vigilance, tempered with justice and equity, and his capacity for inspiring confidence, rendering every legitimate aid in his power and maintaining pleasant relations with the contractor, has much to do with the final result.

When contractors willfully speculate in their bid prices and then depend on their ability to deceive the engineer or his non-enforcement of the specification, they deserve all the trouble, expense and loss they sometimes suffer. Mutual confidence, well justified, spells success to both engineer and contractor as a rule; if the engineer be narrow, mean and impolitic, he will find some contractors able and ready to go him one better and it is well for this engineer to remember that it is a case of one man or at best a few men against an organization.

Mr. Edward P. Adams. — The engineers have heard from the contractors, and while the contractors are here I should like to have them hear something from the engineers. And the reason I speak just now is to emphasize one point that, it seems to me, we should bring out: the fact that the engineer is or should be in a little different position from what the contractors have assumed that he is. It may be true that in public work the engineer has occupied the position that has been assumed this evening. But in private work, or at least on what I have had to do with, and what I have seen other engineers of long experience have to do with, the engineer does not stand in place of the owner against the contractor, but between the owner and the contractor. He has designed the work to obtain the best result possible. He has made the specifications in such a way that the contractor is in no doubt as to what is intended. He has so arranged his specifications that if there are any points which, from the nature of things, are doubtful, unseen, buried, those are to be paid for on a unit basis for quantities which the construction of that work will determine. So that when the engineer presents his specifications there should be just as little as possible of a doubtful element. And my idea is that this method of procedure is as useful to the one as it is to the other, — as useful to the owner as it is to the contractor. I recall now one case where the plans and specifications had been made for a piece of work, and the owner wanted a certain contractor to bid upon it, because he had done other work for him. Of course, naturally, I wanted other contractors to bid, and I called in some that had done work under my specifications. The result was that this contractor that had been named by the

owner bid in the neighborhood of $10 000, while one of the other contractors bid something under $5 000. And the reason was simply this, that this contractor who bid the lowest had been used to working under engineers, and he knew that engineers' work, properly done, would so arrange the plans and the stakes and markings that the work could be done in the most economical manner. It seems to me, therefore, that in private work, at least, the engineer can and should in every case work as well for the advantage of the contractor as he does for the advantage of the owner.

Mr. G. T. Sampson. — It appears to me, gentlemen, that the remarks of the contractors in this case have been offered as criticisms of the existing state of affairs, without suggesting any remedy. Certainly the blanket conditions of the specifications are drawn very arbitrarily, but it is necessary that the engineer in charge of the work should be upheld in his position and he should be recognized as the ruling authority in order that the work may be properly executed. His duty is in the nature of that of a military officer. He stands in the attitude of a military officer, and further than that, he stands as an agent or steward of the owner — the man who provides the money to pay for the work to be done. The whole subject rests upon the fundamental idea of money and profit, as the contract and specifications are prepared to define just what work is to be performed and material furnished for a given amount of money. A contractor goes to the bank, writes his note perhaps in the ordinary course of business, and he knows very well that he has got to pay the interest on that note. He knows that the banker is going to hold him right up to the full terms and conditions of that note, and that money put out at interest throughout the entire world demands just such returns and just such complete fulfillment. He takes such things as a matter of course and not to be changed. The contract for material and workmanship when signed is something of the same nature. Why should its conditions be considered less binding than the obligation of the banker's note? When the contract and specifications are executed the engineer is just as much bound by these conditions as the contractor himself, in that he stands as the agent and steward of the owner to see that the work is properly executed and the conditions fulfilled. These blanket conditions and general terms of the contract stand, we may say, somewhat in the light of the blue laws on the statute books — conditions and precedents brought down from years away back. It may be

that they are proper; it may be that they are unnecessary. Their need cannot be foretold before the prosecution of the work except on general principles. They are there as police regulations—in case of need to uphold the authority of the engineer. They have all been brought into this form which is in use to-day by exigencies in the past in which they have been found to be necessary. They are proved. They are the accumulation of the wisdom of many different men. It is a legal protection, and the law is determined in its judgments largely by precedent. I think engineers as a rule are held by the community at large and by all those who are acquainted with them to be men who are fair and just and honest, as much so, perhaps, as any other branch or set of professional men. Their training, their study, the solution of the problems which come to them, teach them to be honest. They know they won't get good results unless they adhere to the calculations on which their work is based. The engineer who designs a piece of work, if experienced and competent, knows best what is intended to be done; he knows the features of greatest importance; he knows those which are of lesser importance. Then let not the contractor, after accepting work under a specification, assume to vary from its conditions except by consent of the engineer and his employer. Man, however, is not infallible by any means, whether he is an engineer or a contractor. Some errors are sure to show up, and a properly worded contract should have a provision as a fair remedy for the same. It is a rule in business which can safely be adopted, I think, that the man who holds the purse strings is bound to get the worth of his money when he spends it, if he can. The contractor who quarrels with the engineer who is fair and honest and reasonable is putting himself in a wrong position. The minute he refuses to perform work which is specified he takes the ammunition or arguments away from the engineer who, however much he may have the disposition to favor him by arguing on his side with a superior officer or owner, cannot then consistently do so. When the contractor stands in the position of refusing to do things that are specified, the engineer cannot and will not be disposed to favor him or to ask for consideration. But if he does his work completely and thoroughly, and does it in a willing spirit, with the idea of doing the work right for the good of the work as it ought to be, the engineer is in a position where he can go to the man who holds the purse strings — the president of the corporation or any other official to whom he is subordinate — and with clean hands can

argue and persuade and coax, perhaps, for the fairest kind of fair treatment for the contractor in case a loss may result from a cause which was not foreseen. The general form of most contracts is, I think, a matter of precedent. The engineer in charge of a piece of work makes his reputation or loses it according as he is able to execute it successfully or otherwise within the limits of preliminary estimates and conditions. The corporation, public official or trustee, perhaps, that furnishes the money for a large undertaking is held by the banker, when borrowed money is concerned, to a strict accounting for every cent. The treasurer who keeps a record of the expense is accustomed to meet the banker and balance his books to the closest cent. He asks why is not the engineer to be equally accountable. Why shall he not fulfill conditions and obtain results down to the practical limit of precision which his profession teaches and claims, without asking for special exemption or privilege? That, in the abstract, is the power behind the throne, and a contract is prepared to protect the capital invested on a strictly business basis. It is generally recognized that there are uncertainties in contracting work, and the contractor knows it. His profession is a hazardous one. He takes the risks sometimes with large profits, and sometimes loss results. He can't expect to overcome all the difficulties. I think the veterans among the contractors recognize that it is wisdom and good policy and in every way for their interests to refrain from quarreling with their engineers. And when they are at peace, and when they do their work right up to requirements and do not allow the work to suffer at all in its quality, I think they may, as a rule, expect to get fair treatment, and I think they will find an advocate of their cause in case of need in every broad-minded, honorable and competent engineer. I conclude that any energetic contractor who so establishes his reputation for good work and square dealing can easily secure sufficient work to keep his plant employed so profitably that he can afford to turn away and refuse to bid on a proposition which may not be to his liking.

Mr. Frederic P. Stearns. — The paper of Mr. Rollins and its discussion at the meeting by other contractors were interesting, and will, no doubt, lead engineers to improve to some extent their forms of contract and specifications and to act in a less arbitrary manner in directing contract work. Probably all engineers of experience have known of many instances where engineers, generally the younger members of the profession, have given arbitrary decisions which have added much

to the cost of the contractor's work without materially improving the quality of the work under their charge, or they have modified plans in a manner to save some money for their client, regardless of the extra cost to the contractor of such modifications

As far as practicable there should be coöperation between the engineers who direct works and the contractors who execute them, to produce the required result at the smallest practicable cost. This is obviously for the benefit of both parties, because if an engineer unnecessarily increases the cost of a work, subsequent work let under his direction is likely to go at a higher price, and it certainly is a loss to the contractor if he cannot do the work at the lowest practicable cost.

In the writer's dealings with contractors in the past ten years there were very few who were not willing to do good work or who attempted to be dishonest in their dealings. When there has been trouble it has been, as a rule, with those who furnished supplies to the contractors. For instance, stone from one quarryman would come on the work cut substantially in accordance with the specifications, and in such cases an engineer should use many stones which do not come quite up to the requirements, provided the stone when in place would be reasonably satisfactory. On the other hand, another quarryman practically disregarded the specifications in cutting the stones and made them with much larger joints and not true to form. To have accepted such stones would have resulted in masonry of inferior quality to that specified and in paying a premium to the quarryman who did not do faithful work; moreover, only a part of the stone had been received, and if this had been accepted the remaining stones would probably have been even more carelessly cut.

There are several points which Mr. Rollins and others have made with regard to contracts with which the writer fully agrees. For instance, the contractor should not be held responsible for the stability of work designed by others provided the work is constructed as required by the specifications. There are, of course, exceptions to this rule, as it may be entirely proper to require an engine builder or a bridge company or other contractor with a large fund of technical knowledge to be responsible for the efficiency of a machine or other structure.

The writer had supposed that a court would not find a contractor for public works responsible for the stability of a structure made according to the engineer's designs without some specific agreement to that effect, until he was connected with a

case where a masonry dam failed in Alabama. In this case the dam failed, in his opinion, because its design was such that even if well built it would not resist the pressure of water at the height to which it rose in the river during a flood. The judge in this case ruled that the contractor would not have been responsible for the design of the dam had it not been that he had agreed in his contract " to complete the work and the whole thereof," and that it was not wholly completed. The dam was at the time completed in every part which affected its stability, so that the ruling of the judge was practically to the effect that the contractor guaranteed the design of the dam until its completion.

Such a decision, while it may be legal, is not equitable, as the average contractor cannot be expected to have the knowledge required for the designing of such dams, and engineers should endeavor to have eliminated from their contracts clauses which may result in such an inequitable decision.

There are many features of Mr. Rollins's paper with which the writer cannot agree after viewing them as nearly as he can in an unprejudiced way and from the standpoint of public policy. For instance, objection is made to clauses in contracts which in any way give the engineer control over the methods to be used to do the work.

It should be remembered in this discussion that we are dealing as a rule with contracts which are let by public advertisement, and in the majority of cases they are given to the lowest bidder who can furnish bonds and has a fair reputation for doing work, without regard to whether he has engineering ability or not.

The writer has often found it advisable in tunnel contracts to provide for adequate timbering, safety appliances in connection with shafts and cages and ventilation. This control has been found necessary in the interests of the health and safety of the workmen, because many contractors are willing to take risks which ought not to be taken.

As it is advisable not to have divided responsibility, the contractor is made responsible for the safety of the timbering, and the engineer's control is limited by the provision that he may require stronger timbering if, in his opinion, that proposed by the contractor has not sufficient strength.

It is also well that the engineer should have control of the time of removing centers from arches, as there is often a tendency on the part of a contractor who requires the centers for

use in another place to remove them too soon, with material detriment to the quality of the work, and, although the contractor is supposed to be responsible for the work, it is not feasible in practice to condemn completed work unless it is positively bad.

As a rule, the writer believes that the contractor should be left free to plan temporary works, but there should be exceptions to this rule when the works are so extensive that they require technical skill for their design and where the failure of the temporary works would lead to great delay and loss.

As instances of temporary works which I think it advisable to design and pay for, I would include large flumes for carrying the floods in a river past a dam during its construction, and important cofferdams. To leave these wholly to the judgment of the contractor and permit him to bid a lump sum on a work that is not designed seems entirely contrary to the interests of the intelligent and cautious contractor, as some more ignorant or venturesome contractor is liable to underbid him on such work.

The question then arises as to who should be responsible for such designs. If they were not liable to be weakened by the manner in which the contractor conducts his work, there is no question that the responsibility should rest with the party making the designs, but a cofferdam depending upon an earth bank for its stability may fail when the enclosure is pumped out if the water is lowered too rapidly, or, in the processes of excavation, the inner toe may be undermined and weakened and require bracing. It, therefore, seems clearly desirable, in order to avoid divided responsibility, to place the whole of the responsibility upon the contractor and to provide that he may strengthen the cofferdam as much as he wishes or may adopt other designs of equal or greater strength approved by the engineer.

In the case of a flume, which was built before the contract for a dam was made, to carry the water of a river past the site of the dam, the contractor was permitted to strengthen flume if he thought it advisable, and was made responsible for maintaining the flume, because he would necessarily undermine it to some extent by his operations. On the other hand, he could not enlarge the flume, and the other party to the contract was made responsible for the damage, if any, due to inadequacy of size.

Practical experience shows that it is not wise, especially where work must be done within a given time, to permit a con-

tractor to take great risks, like that of the breaking of a coffer-dam, because it inevitably results in delay and almost as inevitably in a suit on the part of the contractor.

Especial objection is made in the paper to the clause in a contract "which makes the chief engineer the sole judge of everything," and arbitration by two persons, with a third one to be chosen in case they cannot agree, is suggested as an alternative. It must appeal to engineers and others that it is difficult, if not impossible, for an engineer who prepares plans, writes specifications and is interested in the construction of work at a low cost, to be entirely unbiased in his judgment. He is likely to lean either in the direction of his employer, or, recognizing his somewhat anomalous position, to lean toward the side of the contractor.

The suggestion of arbitration is always attractive, as one can picture two entirely disinterested intelligent persons of judicial temperament, who will listen to what is told them by the contractor and the engineer, and then proceed to investigate for themselves and reach an entirely fair conclusion; but experience shows that this is an ideal and not a practical condition in most cases.

The cases with which the writer is most familiar are those in which it has been attempted to ascertain the value of a water works property which has been taken by a municipality or a state, by a method which is very similar to the arbitration which is proposed as a substitute for the judgment of the engineer.

In these cases a commission is chosen, nominally by the court, but practically two members are chosen, one each by the two parties. Instead of selecting parties of a judicial temperament, who will be likely to reach about the same conclusion, one side selects a man noted for large awards and the other a man noted for small awards, and after considerable difficulty a third member is usually chosen who is more or less of an unknown quantity. Eminent counsel are engaged on both sides, with assistant counsel, and the country is scoured for experts, among whom will be found on one side those who are noted for the testimony they have given of great valuations of property and the others for lower valuations. The case then is likely to go on for a long time before it is finally concluded. There is one result which is certain to occur, namely, that a considerable percentage of the award is paid to lawyers and experts and for the expenses of conducting the case, and yet I believe the

results are not, as a rule, nearly as fair to both parties as the judgment of the engineer. In such arbitration there is nothing "of the old principle of man-to-man settlement."

A large share of the contracts are drawn by the commonwealth, the cities and the railway corporations, and in a law suit they are generally at a decided disadvantage as against the individual or the small corporation represented by one or more very active individuals; and those who draw the contracts will, and in the writer's judgment should, continue to draw them on the basis of avoiding litigation. He also believes this policy to be in the interests of the fair-minded contractor, who would not gain enough through arbitration or legal procedure to offset the extra time and expense involved.

Strong objection is made in the paper to the use of the words "except as otherwise directed." This provision, together with the usual provision that "the engineer may make alterations in the line, grade, plan, form, dimensions or materials of the work," may seem very arbitrary, but the writer has always assumed that it would not be feasible or even legal for the engineer to make radical changes under the authority given by these provisions and minor changes must be provided for.

It is suggested in the paper that "the contract must be explicit in all its terms"; also that "the engineer should know what he wants when he writes his specification." The writer has yet to know the engineer who, in connection with important work, is able to tell at the time he writes his specifications just what he wants in all details. He may know what he would like if the conditions prove to be as he expects, and yet is likely to learn during the progress of the work, especially where much of it is underground or under water, that the conditions are not what he expected and that there must be some modifications of the views which he held when he wrote the specifications. He should, in writing the specifications, state in them as explicitly as possible what is to be done, but for the benefit of his client and of the contractor there should be such provisions as those above mentioned permitting the engineer to modify the work in view of the further information obtained during its progress.

The contractor does not always recognize that the engineer is not a party to the contract and that he has no right to make any changes except as he is specifically given that right by both parties to the contract.

The writer believes that it would be unfortunate for the

contractor as well as for the other party to the contract if the engineer were not authorized to use his discretion as to changes in plan. Mr. Rollins seems to have given an instance when he says, "Plans showed 6-in. hard pine sheeting driven to a depth of minus 20, and specifications said simply sheet piling shall be driven as shown on plans." In this case, apparently, the engineer was not authorized to make any changes and the owner held the contractor to the requirements of the contract.

In the writer's own experience the authority to make changes has benefited the contractor more frequently than it has injured him, because the modifications of plans have generally been such as to facilitate construction. If a contractor were required to conform to the terms of an explicit contract I think he would soon be glad to return to a form of contract in which the engineer could use some discretion.

Mr. John L. Howard. — In this paper the author has presented the contractor's side of contract work in a very able and comprehensive manner, and doubtless it will do engineers no harm to occasionally "see themselves as others see them."

During the last twelve years it has been the fortune of the writer to be placed as engineer in charge of construction for various public works in this vicinity. During that time, of course, he has come in contact with all kinds of contractors, "good, bad and indifferent." As a rule, however, he has found that practically all of them were desirous of doing good work, and when it could be done without suffering any loss financially, there was very little friction between the engineer and contractor.

The author claims upon the ground of mutuality in a contract that it is the duty of the engineer to guarantee the correctness and reliability of all borings taken under his direction prior to the letting of the contract. It seems to the writer that contractors have no basis for making this claim if the borings are made by a firm accustomed to that kind of work, and if the different samples are properly located and labeled, and the contractor is at liberty to examine them for himself any time before his bid is submitted. When this is done, hasn't all been done that any reasonable contractor has a right to expect? In such case the contractor has all the data that the engineer possesses, and in case it develops during the prosecution of the work that the materials passed through are different from those indicated by the borings, isn't that one of the legitimate risks which a contractor expects to assume in undertaking work below the surface of the ground?

Then the author objects to the clause " or as otherwise directed " in connection with work which he is required to do, but in large public works extending over a number of years it is almost inevitable that changes will be required, either by acts of the legislature or by orders of the city councils, and it seems no more than reasonable that the engineer should write his specifications with these contingencies in view.

In his comments on the requirements in specifications, the author objects to having a certain percentage of sand pass a certain number of sieve when the words in the specifications only call for " clean, sharp sand "; but where gravel is passed over screens having 0.5-in. clear openings, oftentimes the result obtained gives more nearly a good quality of roofing gravel than sand suitable for concrete.

Several of the phrases to which the author takes exception in specifications are very similar to the specifications for work under the writer's direction. In the clause " timber attached to the masonry," where the contractor is required to embed in or attach to the masonry sills and bearing timbers and such other timbers as may be required, the author apparently objects to classifying frames for tide-gates under the head of " timber," but a little farther on in the specifications it is specifically mentioned that bearing timbers for the tide-gates and sluice-gates were included in this item, and the writer fails to see where wooden frames bolted together are any the less timber for that reason.

Regarding masonry joints, the author quotes three instances where it appears that a wide joint has given better results than a thin one, and further on says, " We can't ask you to discharge your inspectors and take everything that comes, but we can and do ask for *reasonable inspection;* . . . but when work goes out of sight, or under ground, or under the sea, a pea-green stone is as good as cadet gray, and a $\frac{7}{8}$-in. joint as good as $\frac{3}{8}$-in."

The words " reasonable inspection " are liable to be interpreted quite differently by different people. To the engineer they might mean compliance with the specifications as written, and if the engineer called for $\frac{1}{2}$-in. joints over all the work, whether under ground, under the sea, or in plain sight, why shouldn't he have them? On the other hand, to the contractor they might mean that the specifications should be carried out to the letter only when the work in question is in some exposed place where the general public would view it plainly each day, but that where the work was out of sight, something not quite so

good, perhaps only in appearance, although just as solid, ought to be allowed. Now every engineer on any large work always allows some divergence from the specifications in small matters not affecting the stability or permanence of the work, but they seldom get any credit for doing so from the contractor, and if the engineer tries to enforce the letter of the specifications in particular cases where it seems to be essential, he is often met with the cry of exacting "the pound of flesh."

It seems to the writer that allowing variations from the specifications is a dangerous custom, causing constant friction between the engineer and contractor, because if it is done once, why can't it be done again and again, and of course it is not fair to the other bidders who perhaps put their prices high enough to cover the cost of the work as called for in the specifications and possibly by that means brought their total so high that they failed to get the contract.

It seems to the writer that this whole question is largely due to the practice of contractors bidding for work under certain specifications with the expectation that if the contract is awarded to them, they will be allowed to do the work in their own customary manner. A large number of them seem to act as if the various clauses, which say that the engineer shall be the authority to decide as to the meaning and intent of the specifications, as to the manner in which the work is to be done, and that the work is to be done to his satisfaction, should read that the contractor is to be the one who will decide as to the meaning of the specifications, and to decide as to the way and manner in which the work is to be done, etc. And it seems to the writer that all of these troubles will be largely obviated if the contractors, upon signing a contract, will make up their minds to comply with the specifications as printed and not attempt to substitute others of their own.

Mr. Alfred D. Flinn. — Mr. James W. Rollins, Jr.'s paper is particularly timely and suggestive to the engineers of the Board of Water Supply of the city of New York, who are just preparing the first large contracts for one of the greatest engineering projects of the times. With many of the criticisms of recent contract practice the writer heartily concurs, but it seems that the author tacitly, at least, assumes a righteous and capable contractor. Such a one, we regret to say, is not always the "party of the second part." The engineers and the legal counsel for a municipality or a corporation must guard against the irresponsible and unprincipled as well as the incompetent bidder,

especially in public lettings in which the lowest bidder must receive the award. Hence, contracts and specifications must be drawn, in the majority of such cases, to provide for dealing with the worst man or organization rather than the best by whom the work may be done.

The difficulty just mentioned has been obviated to some degree by giving to public officials, and by reserving in the advertisements for proposals, the right to award the contract to the bidder whose bid, all things considered, is for the best interests of the municipality or corporation. This puts considerable responsibility upon the chief engineer, as it usually falls upon him to investigate the bidders and report, with recommendations, to his principals. If this power be abused, there is danger of discouraging competitive bidding, and, therefore, unless there is very good reason, contracts should not be awarded to other than the lowest bidder. Opportunity, however, is provided for avoiding the exceedingly undesirable contractor who, under the rigid method of awarding to the lowest bidder, becomes a great trial to the engineer by performing the work unsatisfactorily and possibly at considerable loss to both parties.

In passing, it may be noted that in some places "extra work" clauses are not permitted in public contracts. In such cases apparently the only method for doing additional or extra work is by subsidiary agreement. In some instances, if the cost of such work exceeds a certain relatively small amount, bids must be obtained.

Burdensome requirements and uncertainties in contracts and specifications increase the cost of work and are, therefore, ultimately borne by the owner, the "party of the first part." In any specific case a part of the cost may fall upon the contractor, but if the contractor is to remain in business he must recoup himself for all his costs and make a living profit besides. Fair contracts and reasonable specifications are to the owner's advantage. It is well to remember that the bid price, if a lump sum, or the amount determined by the preliminary quantities and the unit prices bid, does not always represent the total cost of the work, and sometimes misleads the owner or the public official, because through incompleteness or unfairness of the specifications the work is underestimated by the contractor, and bills for extras and other claims materially increase the first figure. The fairer and more complete the specifications and the information furnished the bidders, the more nearly should the bid price approximate the actual final cost.

Engineering is exact only in part, even theoretically. Conditions of construction of civil engineering works involve many uncertainties, especially in long-time contracts for works of great magnitude. Advancement of the arts, improvement of materials, changes in labor conditions and legislation, fluctuations of financial markets and the development of unknown natural elements of the work, all contribute to the uncertainty. These cannot be absolutely predicted, and in some cases hardly approximated in contracts covering a period of years. Therefore contracts and specifications for such works must be sufficiently flexible to meet changing conditions with fairness to both parties. Many questions and emergencies will arise demanding decision by some one in authority with intimate knowledge of the work, and as yet there seems to be no one better qualified than the engineer.

Some evidence has come to almost every engineer with even limited experience in construction work that some contractors bid carelessly, without due consideration of the drawings, specifications and data furnished by the engineers, and without proper examination of the site of the work. It costs money and time to bid intelligently, but bids for important works should not be presented otherwise. This expense might be regarded something as advertising in other lines of business, as one of the legitimate and unavoidable general expenses to be spread over all the business. The actual advertising of the work and many similar expenses are borne directly by the party of the first part, and, of course, ultimately, the indirect expense of preparing bids likewise comes upon the owner.

Contractors, too, have a proneness to take advantage of all chances for extras, and to make many claims for which there is slight foundation. Furthermore, they sometimes fail to comprehend the real purpose and necessities of the work upon which they are engaged. Hence, there is something to be said on the side of the engineer, as the exercise of patience is not wholly on the part of the contractor.

Mr. Rollins objects to the clause frequently found in specifications that inspection shall not relieve the contractor, etc., and that faulty work which has passed inspection may still be rejected. In this connection it is well to bear in mind that inspectors are sometimes bribed or otherwise influenced by unscrupulous contractors, and there is, therefore, need for the provision just quoted. Furthermore, some forms of deception which are practiced in construction, perhaps without any knowl-

edge, and even contrary to the orders of the contractor himself, are not readily detected at first, and hence pass first inspection, but become apparent later. It seems to the writer that this clause does not interfere with the mutuality of the contract, as both parties are assumed to be working to accomplish good results.

Exactness of specifications is desirable so far as feasible, and there is room for much improvement in this line, but the writer believes that steady progress is being made by engineers in this direction. Lack of exactness is caused, as the author suggests, frequently by lack of definite knowledge on the part of the engineer. This is due not infrequently to the fact than an engineer has to cover a wide range of work in the specifications for a large project, and some of the details are relatively so minor that he cannot afford to get exact information in advance. Possibly too much is passed superficially in this way. Lack of suitable standards of excellence seems to be another reason for lack of definiteness in specifications. At times this lack is very hard to supply, especially if the character of the work is different from any which has been performed in the same locality previously.

A contract having been signed, the engineer and contractor should be on friendly terms and work together amicably for the accomplishment of the substantial intent of the specifications. The engineer frequently has power to aid the contractor without in any way being disloyal to his employer or sacrificing the quality of the work. It is only fair to give the contractor the benefit, in such cases, especially if he is in straits through no fault of his own. Over-rigid interpretations of specifications are generally due to the cautiousness of a young engineer whose judgment has not been seasoned by experience, or by the unseemly assumption of authority by a subordinate who really has but little. Such cases must be dealt with by the chief engineer. Engineers and contractors should work together to rid contracts from the unfair and hard clauses introduced largely by timid legal minds, over-anxious for the day of defense in court and totally ignorant of the nature of the work and of the character of the men who "do things" instead of split words. The lawyer, or some of his kind, is a necessary and good friend, but he needs to be brought into closer contact with rock and dirt and concrete, to hear the chug-chug of the drill, the hiss of compressed air and feel the drip of water down the back of his neck as he descends a shaft.

It seems to the writer that little is to be gained by making

other than the engineer the referee under a contract for engineering work. Occasional unjust engineers there may be, but the unjust are to be found among judges also, and among referees of all kinds. An outsider cannot have the intimate knowledge necessary to a fair decision, and time must be lost in informing any such referee or committee of referees chosen to arbitrate. It does not seem boastful to say that, as a class, engineers are fair-minded men. Indeed, the responsibilities which fall upon the chief engineer or his immediate subordinates for any large engineering undertaking, and the whole course of an engineer's training, tend to cultivate honesty and fairness of mind.

Experience and observation lead the writer to believe that the engineer should rarely dictate the methods or plant to be used by a contractor. Occasionally this may be very desirable. When an engineer does thus dictate, it would seem only fair for the contractor to be relieved of the share of responsibility which does not rightly belong to him.

Finally, in discussing any such subject as this, one should continually keep in mind the difference between large works and small, between short-time and long-time contracts, between public and private conditions and between advertised lettings and lettings limited by invitation to selected parties.

Mr. J. Parker Snow. — I agree with the author of the paper in his objection to the one-sided nature of many specifications and contracts. A large part of the trouble, however, voiced by this paper is due to the inherent evils of competitive bidding.

The altruistic ideal of contract work is for a single competent party to make a price that under expected conditions will repay him his capital with interest and a just profit; the owner to pay for unforeseen difficulties that may arise. This is the man-to-man method of our author. But under the present régime, with king Business in the saddle, and every one, owner, engineer and contractor striving for a place ahead, altruism is hopelessly distanced and conditions are far from ideal.

It used to be said that competition was the life of trade; but competitive bidding between our present-day sharp-lined men of affairs is the death of contracting. In their efforts to cut one another's throats they bleed themselves to death. The struggle naturally leads to combination or bankruptcy. It is warfare between individuals, and this was decreed unfashionable when mankind emerged from the stone age.

However, competitive bidding is still with us and must be regulated by specifications and contracts, sealed and unsealed. One bidder among the many will become the contractor and must execute the work under the inspector's criticisms and the engineer's interpretations, and the owner must pay for all. The dreary mill goes round and will continue to grind out profits and losses for the contractors, salaries for the inspectors and engineers and magnificent constructions for the world at large. A better way than competitive bidding will some day be devised, but it behooves us here to try to ascertain what is best in specification and contract writing.

The two essential elements of an agreement between an owner and a contractor for executing work are the plans and specifications. To these may or may not be added a contract.

The plans should show the dimensions, location and details of the work as far as graphics can properly do so. Notes enough to describe particular features should be added, but, speaking broadly, the plans should contain but few written directions.

The specifications are the real meeting ground between the contractor and the owner or his agent. They should show the conditions surrounding the execution of the work, the classification under which it is to be paid for, detailed descriptions of its several items, the quality of its materials and the class of its workmanship. It is the book of reference for the contractor's foreman and the inspector or owner's agent. If it is clear and complete, misunderstandings will rarely arise; if ambiguous or incomplete, the bid is a gamble and the execution a struggle for "points" between the contractor and the inspector.

"Or as directed by the engineer" is a phrase that seems unavoidable in some instances in specifications. But it should be used as sparingly as possible, for it is a confession of inability on the part of the engineer to define what he wants done, and is a manifest invitation to the bidder to gamble on uncertainties.

The fundamental principle to be borne in mind in writing specifications and in interpreting them is the essence of the square deal and the Golden Rule. And something must be left to the spirit of this essence, for it is well recognized that specifications cannot be drawn to be foolproof, and it is nearly as difficult to make them rogueproof.

A contract, if one is demanded, may well be simple. A signed statement that "I, John Smith, for certain considerations, agree to do certain work for John Doe, according to certain plans and specifications, and to his entire satisfaction" covers

the whole ground, and no amount of phrasing will make it stronger.

These three elements of the agreement, viz., plans, specifications and contract, should be coöperative, but neither should repeat what the other contains. Each has its essential field and should be restricted to it. The whole reason to be of these documents and the feature of supreme importance in them is a clear and precise exposition of the understanding between the interested parties of the exact nature and extent of the work to be done.

Our author has made a plea for fair play on the part of engineers and inspectors. He should not expect this unless he is willing to reciprocate. The contractor who pretends to be in doubt as to whether a uniform color was intended of all the stones in a piece of masonry or simply for each stone so that a speckled hen effect would obtain, when the specification read, "The stone used in the work . . . shall be uniform in color," deserves to have to furnish mosquito frames by board measure and have the mitered corners deducted at that. Speckled masonry may be as strong as any other, but sometimes other features than strength are essential.

If conditions arise that neither the engineer nor contractor could foresee, the former is a Shylock, not fit for his profession, if he will not help the latter as much as his loyalty to the owner and the regulations of his superiors will admit. On the other hand, the contractor who searches for loopholes to dodge the true intent of the agreement deserves all the penalties and adverse judgments that the courts hand down to him.

Competitive bidding is the mother of a large family of expedients, good and bad, for cheapening construction, as well as a bat-winged brood of base attempts to dodge the true intent as above. Until we can supplant the wretched wench with some fair goddess of justice who will handle the scales so that fair play shall be to the interest of all parties concerned, let us of the engineering ilk make our drawings clear and correct, our specifications full and definite and our contracts short and free from one-sided attempts at making law. Let bidders name a fair price for each and all items of work without banking on unbalanced estimates or strained constructions of obscure points. Above all, let bidders abstain from attempting to freeze out or cut the throats of rival bidders. Let contractors execute the work in a spirit of willingness to do what they bid to do, and let owners allow sufficient time for working out details before bidders are called upon the scene.

Engineers, when writing specifications, will welcome hints from contractors, with a view to clearness and smooth working, and I for one am obliged to the author for bringing out the points set forth in his paper. When civilization shall have advanced so that competitive bidding is history, a part of our present difficulties will have disappeared.

Mr. Leonard C. Wason. — The writer has read Mr. Rollins's paper with a great deal of interest and indorses all that he says. As the company with which the writer is connected does a different class of work from Mr. Rollins's they have had some different experiences, which may be of general interest.

As it is generally known that the members of the writer's company are capable of designing any reinforced concrete structure that is built, many owners come to us for designs in order to save the engineer's commission. The word "owner" is here used to mean the party who pays the bill, whether it be a private individual, company, city, town, state or nation. With the exception of work simple enough for any one to design, it is the policy of the company to advise the owner to employ an engineer or architect, to pay him his full commission and to make him earn it, and to illustrate the various ways an engineer will earn his commission by saving the owner expense that would be incurred if he attempted to do his own work. This is merely stated to show the attitude of the writer towards the work of engineers and architects, and that the criticism which may be offered is in the spirit of the old phrase, "The world may flatter, but it is your friend who tells you your faults."

In the writer's opinion it is very frequently the fault of the *owner* that unfair articles are inserted in contracts. In some cases he does not pay a full commission and the engineer, therefore, will not go to the expense of finding out and assuming responsibility for the accuracy of borings or other uncertainties encountered. A few engineers throw responsibility for all uncertainties to be encountered upon the contractor to save themselves the trouble of the careful study necessary to determine the exact conditions. Sometimes an owner does not allow an engineer sufficient time to do his work thoroughly, and therefore he is compelled to resort to phraseology of contracts which relieves him of all of his own responsibility and requires the contractor to assume it.

Engineers in the permanent employ of an owner are liable to become biased — it may be unconsciously, but nevertheless certainly — from long continuation in one line of service, and they look and act from the viewpoint of the owner rather than

from that of a disinterested referee between the owner and the contractor. Public works departments of cities, states and the United States and the railroads employ a permanent staff, and it is the writer's experience that the contracts and specifications from these sources are subject to criticism most generally, and that there is little criticism to be found with the work emanating from private sources. The chief engineer too often takes the word of an inspector without verifying his statements and without question, and decides a point upon this report, and to maintain a system indorses the report of the inspector, even though later it is found to be wrong. Too frequently inspectors are novices, it being their first employment at engineering, and they are for this reason many times incompetent. Occasionally a thoroughly competent one finds the work carried on satisfactorily, and because he makes no criticism to his chief, it is assumed that he is not doing his duty and he is transferred, or he is ordered to find fault where no fault exists. There is something wrong in the viewpoint of the chief engineer who holds such a view. A competent and honest inspector is a real aid to a contractor.

The writer has largely withdrawn from public work on account of unfairness encountered not only in contracts and specifications, but in the system of administrating them, and because this system has brought into this line of work a class of contractors who are plungers and who gamble on conditions, cut prices and skin the work when they can. Under such conditions it is hard to get a fair price for the work. One-sided, unfair contracts foster this class of contractors, while fair and mutual ones will bring forth a better, honorable and honest class in larger numbers. The position taken by a number of first-class contractors before bidding on a given piece of work is first to see if the work in itself is desirable, then to read the contract and specifications, consider the personal equation of the engineer in charge, whether he is reasonable or unfair, and then figure or decline to figure as the case may be.

The fact that no contractor ever becomes rich proves that the average of all work is done cheaply. To literally fulfill some contracts and specifications the contractor ought to know more than the engineer and to have made a more thorough investigation than the engineer has before he puts in his figure. In the short period of time allowed for making up a bid, it is never possible to completely review the engineer's work to see whether it is right or wrong, even though the contractor has the technical

ability to do so; nor should he be asked to spend the time and money necessary to do this when bidding in competition.

It would be a distinct advance if owners as a class could be made to realize that there is *positively nothing* which raises a bid like asking a contractor to assume *uncertainties* which may be encountered, and that the engineer earns his money by eliminating such uncertainties, thereby reducing the cost probably more than his own commission amounts to and perhaps several times over; and secondly, that by eliminating all unfair and unreasonable clauses a much better class of bidders can be obtained; thus good workmanship can be secured and usually at a lower price than can be obtained from the cheaper class of workmen who gamble on the uncertainties. Insufficient time to prepare a careful bid is the next most important item in raising the cost of work.

The engineer tries to please his owner and frequently is obliged to do things he does not himself approve, but when the owner realizes it is for his own financial benefit to be fair, there will be little fault to be found with the engineers by the contracting fraternity. Let the owner assume all uncertainties. If difficulties arise, he pays the price he would pay anyway, and if they do not arise he wins this amount instead of the contractor. This method implies percentage or lump-sum profit work on the uncertain items, but he has the safeguard of having to pay only once for having his work done right. If the work is not done right the first time, or if carelessly or negligently handled, the owner is no more subject to pay the price of making the work right than if it was done on the ordinary lump-sum contract basis. When the uncertainties Mr. Rollins enumerates are eliminated, there will be a different and better class of contractors and a larger number of them can be found to undertake work; thus there never need be any danger of lack of competition or of an incompetent or negligent contractor obtaining the contract. The owner and contractor ought to become acquainted and friendly; thereby trouble may be smoothed away to the mutual satisfaction of both sides.

Mr. Rollins, in closing his paper, alludes to the courts being left for the Boston Elevated cases. In this connection the writer would like to call attention to one clause from a Boston Elevated contract for desirable work on which he declined to estimate because, in his opinion, it was an invitation to trouble.

It is well known that the Boston Elevated and other large corporations are held up for blackmail and are sued for causes

just and unjust. This clause, which is as follows, endeavors to shoulder on to the contractor trouble which may be real or only *alleged* to be real: "In case any claim is made against the railway company, which claim is based upon, grows out of, or is *alleged* to grow out of, anything done in reference to matters contained in or incident to this contract, the railway company may retain such sums as in the judgment of its president will indemnify it against any loss"; and further, "In addition to damages indicated above, may deduct reasonable charges incident to the investigation and defense of such claims." It is impossible for the contractor to allow for this contingency in advance adequately, and to make an allowance for a contingency that may not arise would require the railway company to pay more for the work than it need to. Labor leaders would have no better weapon than this for attacking the contractor. They could trump up a claim, press it with vigor and in this way hold up money and put the contractor to considerable expense for which he was in no way legally to blame. Allowing the railway company to settle the case at his expense, including the costs, without consultation, thus permitting a party who is not financially interested in the expense to become your attorney in fact with full powers is a usurpation of justice which the writer is unwilling to grant. This same contract also requires the contractor to guarantee the sufficiency of the engineer's plans and specifications in all particulars.

It is hoped that all contractors will protest against contracts of this nature. Those who will not are deserving of all the trouble that can come to them.

Mr. James W. Rollins, Jr. — After careful study of the discussions, it seems that many of those members participating agree upon most of the principles in the original paper.

Some admit that the claims are all right for honest contractors, but contend that to protect themselves engineers must make a contract and specification for a dishonest one. Almost every contract for public work provides "that the work shall be let only to bidders who can furnish satisfactory evidence that they have the ability and experience to do the class of work called for, and that they have sufficient capital and plant to enable them to do the work successfully and to complete it within the time named in the contract." Why isn't this clause protection enough for any engineer, and sufficient ground for him to reject the bid of any dishonest or incapable contractor and let a good one have the work? Most contractors must com-

pete for work; few get to be so honest and reliable that they can live on contracts which they "select as desirable." We have some ambition at times to bid on public works, and we know we must bid against everybody, good, bad and indifferent, and almost always with the knowledge that we can't get the work unless we are the lowest bidders.

We contractors also know perfectly well that the personality of the engineer can make or break us, and the writer leaves out in this statement any question of actual honesty or dishonesty; that is, in plain words, if an engineer demands in full every and all conditions of the specification to be carried out the job is a failure financially. Opinions are expressed in the discussions that such a contractor should fail, that he has agreed to do certain work and that he should be made to do it, made to do *perfect* work. Are engineers *perfect?* Can perfection be obtained in many things — in any thing? Perfection is *exact* compliance with specifications; but may I ask, Is the work better or stronger because a joint is *exactly* ½-in. or the color is the exact shade called for, especially as most masonry is discolored in six months after being laid? But as long as we have engineers we shall have the *exact* ones, who will have their pearl gray color and their ½-in. joints, their measurements to a thousandth, with perhaps their feet wrong. They are surely the "stewards" who will get their 100 cents on a dollar and the pound of white sugar they ask for; and what else? — a reputation among contractors, and the honest ones too, so that after having been "led once to the slaughter" they refuse to bid on any more work to be done under such engineers, or bid so high that they will not get the work. The writer knows of such engineers — perfectly honest but not just and fair — men for whom contractors will not work at any price, and whose reputation even among their fellow-engineers and their superiors is that of a "*grandma.*" Cannot you engineers in charge of work train up your young men to use their judgment, to be free to treat contractors fairly, get good, true, honest work without fussing at some trivial lack in detail which amounts to nothing, but to correct which means loss of time, money and patience; to work in harmony for the best of everybody?

Certain engineers seem called upon to assume all responsibility of *design* of temporary work, and then disclaim responsibility in results. Hasn't the time about come for such men to realize that among the contractors are engineers who know their own business, and who knowing it will be thoroughly able

to protect their own interests; or who, if they are not themselves technical men, are good enough business men to get an engineer to figure out for them anything necessary? Why is it necessary to furnish plans of centering, ventilation, etc., of tunnels, which matters, in the judgment of the writer, can best be provided for by the contractors, who make such work a specialty, all done upon the ground of safety to men; and leave out of their plans the handling of explosives? As far as the writer has knowledge, the underground work in the New York subways and tunnels, in the Pennsylvania Railroad work, also the subway work in Boston, has all been done by the contractors — they making their own plans of temporary work and being responsible therefor. In the years of work done by the writer on railroads, where certainly the danger of loss of life is greatest, the railroad engineers do not pretend to say how a contractor shall do his work, in its temporary nature. Any engineer has every right to stop a contractor when he goes wrong; so why entail a lot of ill-feeling, disputes and trouble, and also do a great injustice, by prescribing all details of temporary work, and then holding contractor responsible for it, design and all? *It's not a square deal;* we contractors can stand on our own feet, do what is necessary, and be responsible for it.

Mention is made that never does an engineer know what he wants when the contract is let. How then does he expect the contractor to make an intelligent bid? — for if the engineer doesn't know, the contractor surely doesn't. It is admitted that plans cannot be perfected in a short time, but surely an engineer should know what kind of cement he wants as to chemical analyses; what kind of sand he wants as to size; what size piles he wants, and all such matter, when he writes the specifications. As to plans being perfected before contract is signed, the writer recalls two large contracts executed by his company, almost adjoining, and built under almost exactly the same conditions. On one contract plans were made in detail and a lump sum price submitted, and so well did the engineers do their work that on a contract of $600 000 there was never a charge for extra work on account of any error of plan, nor any row with engineers over meaning of plans or specifications. On the other job, work was let by items, on a general plan. When the detail plans came out, in many places most expensive forms were needed; concrete shown in massive walls was changed and built full of economy holes; then walls were built with steel reinforcement; that is, steel concrete was substituted for ordinary concrete, at the

latter's price. We all expect changes, and that such are necessary; but we do not expect, and we do object to, changes such as mentioned, made to save money for owners, and cost *us* money to execute. When such changes come, discussions, disputes and bad feelings arise, and unless the engineer is fair enough to admit the value of such changes and pay for them a loss falls to the contractor. This experience has led the writer to always favor a lump sum contract.

The writer still sticks to the dictionary as to what timber is — *a single stick of wood;* and a *frame* is made of *timbers* fastened together.

Comment is made on the " as otherwise directed " clause; and by one member to the effect that such a clause is necessary because the legislature or city council may order changes, and that the engineer should have that in mind — to do what? — *to be able by law* to cause the *contractor* loss, with no redress?

One member states that we criticise existing affairs and offer no remedy. We do offer a remedy, and in two words: give us a " square deal."

When engineers draw up a contract — and if they don't draw it up they are responsible for it — with the words " do the work and the whole thereof " — words which mean little to a contractor amongst the great mass of words in a contract, but which may mean under the courts' decision the loss of everything he owns, and because an engineer *didn't know his business* and design his work well — it seems to the writer a gross act of injustice and a great wrong; it is the act of some weak, cowardly mind, who does not dare to stand by his own work and take the honor or blame as either may come.

The writer proposed to bar six stipulations; and, to emphasize the matter, will repeat them:

First. Disclaiming responsibility for soundings or other information as to the character of the work.

Second. The insertion of clauses which make any contractor's estimates worthless by adding, " or as otherwise directed."

Third. Making the contractor responsible for work for which engineers make the plans or require their approval to any made by contractor, and where engineers reserve the right to entirely control the manner and means of construction.

Fourth. Holding contractor responsible for work which has passed inspection or has been done under direction of engineer, or his agent, or inspector, unless fraud can be proved.

Fifth. Making the engineer the sole referee in settling all claims.

Sixth. The right to stop work, or any part of it, if for the interests of the company so to do, without allowing the contractor anything for the loss such action might bring to him.

With these eliminated from contracts, with specifications explicit in defining qualities of material wanted; and with a fair interpretation of such specifications, having in mind the source of supply and the work in hand; then, in the opinion of the writer, we shall have the "*square deal*" we ask for.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1907, for publication in a subsequent number of the JOURNAL.]

ANNUAL ADDRESS.

The Engineers' Club in Its Relation to the Future St. Louis.

By W. A. Layman, President of the Engineers' Club of St. Louis.

[Read before the Club, December 19, 1906.]

Gentlemen of the Engineers' Club, — It has been the custom for the retiring President to present to the Club at this time a brief paper discussing the general welfare of our organization in some important respect. I have therefore selected as my theme to-night, " The Engineers' Club and its Relation to the Future St. Louis."

This Club has been an institution justifying by its long record of conservative engineering discussion the public confidence which it evidently receives. Its members have comprised throughout its existence substantially all the leading engineers of the community irrespective of their individual lines of professional demarkation. It is to-day in healthful, vigorous condition promising even greater usefulness to its membership and the community at large than has existed in the past. We may with propriety entertain no small degree of pride in the record we have made as a Club, steering our course so as to avoid contamination from political and social influences and maintaining an engineering integrity unusual in degree.

In looking back over this record of the past, seeking to balance up the achievements of the Club against its possible opportunities for good, I have been deeply impressed with the evidence of wisdom shown in its creation, and in its direction over a period of thirty-eight active years. I trust we may move forward with few deviations from that course of careful conservative public and professional policy which has been the secret of our success.

I have therefore turned my eyes from a criticism of the past to a contemplation of the future, seeking to discover wherein we may be of greater value to ourselves and to the community in which we live. At a recent meeting of the Club our subject for discussion involved a review of the work accomplished by the Mayor's commission on the study of the terminal situation. One of our speakers tersely remarked that in his

opinion the Engineers' Club was getting into the field a little late, implying that we could have served a better purpose had we taken a creative rather than a retrospective interest in this terminal situation. I deem this comment pregnant with suggestion for the Club. We, with numerous other organizations in the city of St. Louis, are looking forward to a time when our city will have, not a population of one million as some of our enthusiastic citizens are talking so much about, but instead a population of two millions, and rapidly thereafter larger and larger numbers. Why may not this Club, with wisdom and propriety, give itself seriously to the contemplation of such an era of civic expansion? It is essentially the business of the engineer to serve the public constructively. Individually, we live in a constant atmosphere of creative work. Why may we not collectively and as a Club take on this same relation to the general public? I offer the suggestion that we seriously give ourselves as a Club to the study of the needs of the St. Louis of 1925. There are several reasons justifying such a policy on our part, some of which I may briefly recite:

St. Louis as a city of two millions population must undergo a physical metamorphosis involving problems of engineering character of very great importance. We are face to face now with the consideration of such questions as a rapid development of water supply; a sane and economic disposition of garbage and sewage; the evolution of a system of rapid transit; the large expansion and reorganization of our general system of passenger and freight railway terminals; the evolution of a general scheme of beautification for our city; a reconstruction of our ideas bearing upon the wagon transfer of merchandise, as well as pleasure and business travel by carriage; the creation of some underground means of transportation for both passenger and freight. These topics are the suggestion of present current discussion. It is difficult to predict the further important problems of an engineering character which will be developed by the process of rapid evolution through which our present generation is passing.

It is pre-eminently the business of the engineer to link the facilities and conditions of the present with the requirements of the future. Therefore the people of St. Louis will in the near future, even more than at present, be pressing upon us as engineers the solution of the questions herein involved. I say they will be pressing upon "us," meaning by "us" the membership of this organization. I should qualify this by saying they will be pressing the solution either upon us or upon *other* engineers non-

resident in the city of St. Louis. We *think* we are here to do all this work for the city of St. Louis; we *hope* to do it. What is the best manner of proceeding, therefore, to secure to ourselves the doing of all these great tasks from which we may expect engineering and financial remuneration commensurate with the service performed? I offer the suggestion that this may be accomplished by constituting the Engineers' Club of St. Louis a forum wherein to seriously study and discuss these questions of our future public needs. Let us assume a creative phase for our Club work; let us select standing committees, the functions of which will be the study of specific phases of the future engineering conditions of the city of St. Louis. Let us have committees on rapid transit; expansion of terminals; beautification of the city and other lines of public need hereinbefore alluded to, and let us impose upon these committees the definite and immediate task of taking up the study of the requirements of the prospective city of St. Louis with the purpose of reporting back to the Club annually, or at more frequent intervals, if desirable, a general discussion of the questions particularly assigned to them.

It may be asked whether this is not encroaching upon the private responsibilities of the individual engineer. I think not. Every progressive engineer is naturally developing himself along some particular line, but in his individual field he has small opportunity to impress public sentiment with the views he may individually entertain. With all these topics it is essential to bring the public into a realization of what the city will eventually require. This could be done in a peculiarly effective way through the medium of an organization such as ours, the reputation of which, for conservatism, has been established by a record of thirty-five years. It may further be asked if this is not asking a measure of self-sacrifice on the part of our busy individual members going beyond the reasonable demands of our Club organization. I do not think so. Our leading engineers must study all these questions carefully and continuously if they expect to do the engineering work for the city of St. Louis. Why not give the fruits of this study to the public by a progressive presentation of the results arrived at through the medium of our Club meetings? It will then be realized by the public that in the city of St. Louis there are engineers who have their minds and talents concentrated upon these questions, men who know what has been done elsewhere and therefore men who are competent to attack actual solution of these local problems when the time arrives for the municipality to take them in hand.

There have been occasions in the past when important civic commissions have been partly, if not fully, made up of engineering talent called from outside the city of St. Louis. There will be occasions in the future, if our own engineers continue silent on all these questions of public interest, when eminent engineers from elsewhere will be invited to do these prospective important tasks. Let us prevent this by having our Club become a non-partisan factor in a consideration of these future needs. Let us freely give, through the Club, from time to time, the information we have at hand, and the views we have formulated as to our public needs. Let us conduct a program of individual education through the medium of work for our Club. Gentlemen, you see now what I mean by my subject, "The Engineers' Club and its Relation to Future St. Louis." I do not invite a departure from a policy of conservatism; I rather invite a campaign of creative *work* — a reward for which may be eventually disclosed in the acceptance by the public of comprehensive schemes of engineering works proposed for the city of St. Louis by the Engineers' Club of St. Louis, and executed by the individual resident engineers of the city of St. Louis.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIX. AUGUST, 1907. NO. 2.

COMPARATIVE RÉSUMÉ OF THE SEWAGE PURIFICATION TESTS AT COLUMBUS, OHIO.

BY GEORGE W. FULLER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Sanitary Section, December 6, 1905.]

ON December 6, 1905, the writer had the pleasure of giving an informal talk before the Sanitary Section of the Boston Society of Civil Engineers on the results obtained from a quite extensive series of sewage purification tests conducted at Columbus, Ohio, for about one year under the immediate charge of Mr. George A. Johnson. These tests formed a part of an elaborate series of studies made to aid in improving the municipal works of Columbus as projected by Mr. Julian Griggs, chief engineer, and now being executed under the direction of Mr. Henry Maetzel, chief engineer since March 1, 1906, and Mr. John H. Gregory, engineer in charge.

At the time that the informal talk was given, the detailed report of Mr. Johnson on these sewage tests was in press. With the appearance of this report in April, 1906, the need of editing the stenographic notes of this talk largely disappeared. However, it has been thought that it might be useful if some of the writer's notes upon this subject were put in shape so as to show in a comparative way those features where there were discrepancies between or confirmation of the Columbus experiences and those elsewhere.

On behalf of Hering and Fuller, consulting engineers on the new works at Columbus, the writer took active supervision of these sewage tests from the outset, and has had the good fortune

to have discussed the outcome at considerable length with various leading European workers on the occasion of two visits to Europe during the past year. He has also had the benefit of the views of Mr. Johnson who, during the past year, has noted the applicability of the Columbus data to problems in various foreign lands, and who has studied these data in the light of numerous other experiences in this country.

The Columbus Sewage Problem.

Columbus is a city of about 175 000 people. It is situated slightly southwest of the center of Ohio and about 100 miles from Lake Erie. It is upon the upper portion of the watershed of the Scioto River. This river flows nearly due south from Columbus for a distance of about 100 miles, where it enters the Ohio River.

Geologically, Columbus is situated near, but still within, the southern limits of the glacial drift formation. The city is located in a limestone valley, and while there are deposits of coarse sand and gravel in the neighborhood, they are all overlaid with so much clayey and impervious material that it is not possible to obtain locally any natural sand filtration areas such as are so conspicuous in solving purification problems in New England. And, furthermore, those areas of porous sand and gravel which are to be found near Columbus are in most cases very low with reference to the ground water level. The site of the plant which is now being built has, some three or four feet beneath its surface, quite a thick stratum of porous sand, but it is but very slightly above the ordinary water level of the adjoining Scioto River and is entirely out of the question for any practical use in sewage purification.

Hydrographically, the conditions at Columbus are these: The Scioto River is joined by the Olentangy within the city limits. The two streams together have a drainage area of 1 665 sq. miles. The low stream flow is from 30 to 50 cu. ft. per sec., and is noted for many days and weeks at a time. On the basis of $3\frac{1}{3}$ cu. ft. per sec. as a dilution necessary to avoid nuisance from the sewage of a population of 1 000, there would be a permissible limit at such times perhaps of 10 000, as the number which could drain directly into the Scioto River. At times of flood flow the other extreme, of course, is reached for the run-off of that section; and under these conditions the sewage of over a million people could be disposed of without creating any nuisance. During low water the Scioto River is usually unsightly and foul smelling.

To trace briefly the efforts which have been made during the past ten years to solve this problem, it is necessary, first, to mention the report made in 1898 by Mr. Julian Griggs (who was the city engineer of Columbus up to March 1, 1906), and by Mr. John W. Alvord, consulting engineer, of Chicago. These gentlemen made an elaborate report, which treated of the ways by which they could intercept the sewage, collect it at main pumping stations and deliver it to a purification site. As to the method of purification, they recommended screening and filtration through coke, — practically contact filtration as we understand it to-day. They got out preliminary designs for a plant of 20 000 000 gal. daily capacity, and provided 40 acres of coke filters. It was their idea that it would be wise for the city to build about two acres of those filters at first, and then, after testing them for a year, to design the remainder of the plant in accordance with the experience of that first year. The city did not then have funds to consider the matter, and the problem remained in abeyance for about two years. Then a city sewerage commission, under the following administration, took up the subject anew and the city engineer at their request made estimates of a system involving septic treatment and intermittent filtration, the idea then having gathered strength that contact filters would be too expensive.

Following those estimates a scheme was prepared of a temporary nature by which the sewage was to be treated in septic tanks alone. On the plea of economy that project was put before the Ohio State Board of Health in the autumn of 1900 and was disapproved by that board on the ground that there was no evidence to indicate that it would prove suitable or adequate at times of low stream flow. In the spring of 1901, Mr. Rudolph Hering, of New York, was called in consultation, and, after reviewing the local evidence, approved of the plans for interception, pumping stations and other general features, and advised that they build a plant consisting of septic tanks or sedimentation basins, and follow that treatment by intermittent sand filtration through beds of artificial construction, built of material brought from the shores of Lake Erie, some 100 miles distant. He, too, advised that only a portion of this plant be built at first and that the remainder be designed after they had gained practical experience in the use of a portion of the plant for at least a year. This project was approved by the Ohio State Board of Health, subject to some qualifications as to the manner in which the plant should be built in a tentative way,

and also subject to reasonable requests as to care in the manner of operation.

The State Board of Health at that time also stated that they considered the evidence quite limited as to the correct capacity of septic tanks and sand filters under these conditions, and formally advised that the matter be thoroughly investigated before such a large sum of money was expended. The matter from that time remained in abeyance until the autumn of 1903, when, owing to a change in the municipal code of the cities of Ohio, as to their financial means, the people came to vote on the issuing of bonds for improved sewerage. That vote, in November, 1903, for an issue of $1 200 000 for improved sewerage and sewage disposal works, was favorable.

The Columbus Testing Station. — The first step toward carrying out these improvements was a decision on the part of the Board of Public Service, upon the advice of their chief engineer, Mr. Griggs, and consulting engineers, Messrs. Hering and Fuller, and also the State Board of Health, that a testing station be built. The position was taken that the expenditure of a sum of money representing roughly the interest on the capital involved for one year could well be spent and result ultimately in decided economy. Councils passed an ordinance appropriating $46 000 to be devoted to the purpose of a testing station, in which there were to be obtained practical data to show the cheapest and best way of purifying the sewage to the extent necessary under the local conditions.

The station was placed under construction in May, 1904, and its equipment was completed in the following July. It was operated under the charge of Mr. George A. Johnson. The more important details of this station have already been set forth so thoroughly in engineering papers that it is necessary to speak but briefly as to its arrangement. (See *Engineering News*, October 20, 1904, and *Engineering Record*, November 19, 1904.)

In short, this station was designed to purify at least 350 000 gal. of sewage daily, and to test all the well-known methods for preparatory treatment, involving plain sedimentation at low and at high velocities, septic treatment, chemical precipitation and coke strainers. For the final treatment there were twenty-one intermittent filters of sand brought from Lake Erie and in which the sewage, after various preparatory treatments, was treated at different rates, with the special view of making those rates as high as possible under local conditions. In addition to the well-known method of intermittent sand filtration, there

were also filters of coarse material, contact filters and sprinkling filters, which were operated in different ways and with sewage which had received different kinds of preparatory treatment. In all there were about forty-two devices.

Mr. Johnson had on his staff fourteen men, nearly all of whom were technically trained. His inspectors, who read meters, collected samples, etc., were, for the most part, recent graduates in engineering at the local university.

Sampling Schedule. — In the case of the crude sewage, samples were collected at half-hourly intervals throughout the twenty-four hours, and the several portions then mixed for analysis. In order that the sewage of no one day in the week should receive more than its proportional weight in the study of the composition of the crude sewage, a schedule was arranged at the beginning of the tests whereby no samples were collected on every eighth day. The day on which the sewage was not sampled was thus moved forward one day each week, so that no day was omitted from the sampling schedule twice in succession, but only after the lapse of seven weeks.

In the case of the sand filters and the contact filters the hours of dosing were varied throughout the tests in an attempt to cover all conditions. The day on which the sprinkling filters were sampled was moved ahead one day each week.

Amount of Analytical Work. — The number of analyses which were made in connection with carefully gathered engineering data was, perhaps, a little unusual. From a majority of the devices where there was a continuous flow, samples were collected at half-hourly or hourly intervals. Of the raw sewage alone there were 13 536 different portions collected. In round numbers, 9 000 portions were collected of the effluents from the various tanks in which sedimentation played a part. In the case of the effluents from the various sand filters the samples were collected after receiving and carefully mixing the effluents in measuring boxes. Average samples of the influents were collected as the filters were flooded. Samples from the contact filters were collected at weekly intervals near the beginning, middle and end of the emptying period and the several portions mixed in aliquot quantities for analysis. The same procedure was followed in the case of the influents. Bacterial samples were collected at the same time, and the results of the individual analyses were averaged.

In the case of the sprinkling filters samples were systematically collected at weekly intervals. On the sampling day

portions of the influent and effluent were collected at hourly intervals throughout the day, and the 24 portions were then mixed and analyzed. The individual portions were collected in 4-oz. bottles, which were completely filled, tightly stoppered and placed on ice. Bacterial samples were collected from the influents and effluents at 7 A.M., 11 A.M. and 4 P.M., on the regular sampling days, each sample being plated as soon as collected. The results of analysis of the three samples were averaged to give a representative mean.

In all, 3 270 complete chemical analyses were made; 4 356 bacterial analyses; 483 additional analyses for suspended matter and 130 analyses of sludge.

Degree of Purification Required. — At Columbus it was required that the sewage should be purified so as to make it non-putrescible and of a fairly presentable appearance. It is some 200 miles to the intake of the nearest public water supply and while it is not doubted that disease germs in gradually lessened numbers can travel this distance, it is believed that they will only be present in such quantities that their influence will not materially add to the task of purifying the Ohio River water under existing local conditions for some time to come.

As to the quality of the water in the Scioto River below Columbus, the proposed sewage purification works should entirely eliminate all questions of nuisance. It is not expected that in its raw condition this river water, even with the sewage of the city of Columbus eliminated from the Scioto Valley, would be fit for drinking purposes. This is due, of course, to the pollution entering the river from the rural population and a few small towns and villages above Columbus.

It will be seen that this problem differs quite materially from those where shell fish industries are intimately involved, as in the instance of Baltimore, or in the case of the disposal of the sewage of small towns resident upon the drainage area of an unfiltered water supply such, for instance, as Natick, Framingham and Marlboro, Mass., in their relationship to the Sudbury and Cochituate water supplies of Boston.

General Significance of Sewage Tests such as those made at Columbus.

It was the purpose, in solving the Columbus sewage disposal problem, to collect data first which would enable us to learn as definitely as we could what the problem was we had to face, and then the ways and means by which the problem could be solved

at least expense. In many ways the sewage disposal problem of Columbus has been conducted in a somewhat similar manner to the well-known water purification investigations at Louisville, Pittsburg, Cincinnati, New Orleans, etc.

While in some ways it may be said that there was almost nothing new in the devices tested at Columbus as to their applicability under local conditions, it is not out of place here to refer briefly to the fact that this idea of fitting various procedures found satisfactory elsewhere to the actual local conditions of a specific problem has had a great deal to do in advancing the art of water and sewage purification during the past 15 or 20 years. The writer quite recently looked into this subject, and found that investigations upon water and sewage purification projects in this country have been conducted to the extent indicated by the following experiences:

TABLE No. 1.

List of Special Investigations on Water and Sewage Purification.

Place.	Date.	Work.	Approx. Cost.
Lawrence, Mass.	1887 to date	Water & sewage	$175 000
Providence, R. I.	1893–94	Water	5 000
Louisville, Ky.	1895–97	,,	47 395
Reading, Pa.	1897	,,	1 500
Pittsburg, Pa.	1897–98	,,	36 286
Cincinnati, Ohio	1898–99	,,	41 588
West Superior, Wis.	1898–99	,,	2 000
Washington, D. C.	1899–1900	,,	8 000
Richmond, Va.	1900	,,	2 000
New Orleans, La.	1900–01	,,	23 606
Worcester, Mass.	1900 to date	Sewage	37 000
Philadelphia, Pa.	1900–05	Water	172 000
Springfield, Mass.	1901–03	,,	18 000
Harrisburg, Pa.	1903–04	,,	25 000
Mass. Inst. Tech., Boston	1903 to date	Sewage	20 000
Columbus, Ohio	1904–05	Sewage and water	44 004
Waterbury, Conn.	1905 to date	Sewage	10 000
Total			$668 379

In Europe the tests are not, as a rule, conducted in precisely the same way as at Columbus, but they are run side by side with the operation of plants in practice. The same sound process of stepping from the unknown to the known is largely utilized, however, and one of the most gratifying features in the development of sewage disposal problems is the gradual development side by side of the engineering, chemical and biological aspects of this subject.

The Columbus Sewage.

There were two features towards which unusual attention was paid at Columbus. The first of these was to find out what was the composition of the local sewage, and the second was to find out the best means of giving it a preparatory treatment by which the major portion of the suspended matter, or sludge, could be most advantageously removed. The first feature will be taken up here as it is essential for the presentation of the second one.

The testing station was located at the foot of the main intercepting sewer, draining the business portion of the city and a large portion of the manufacturing and residential districts. This main sewerage district has a population of about 100 000, and of that number about 75 000 are connected with the sewers. This intercepting sewer had an average flow of about 9 000 000 gal. daily. It was practically as representative of the future sewage of Columbus as it was then possible to get. The sewage there is not essentially one from a manufacturing community. There are a good many small iron works, foundries and the usual quota of breweries, tanneries, laundries and dye works, but except at times of very dry weather flow there were only short periods at a time when any manufacturing waste made itself very conspicuous at the testing station.

This portion of the sewerage system of Columbus, as should have been already stated, is on the combined plan. Future additions are to be on the separate plan. The public water supply there is very hard, and there is the usual leakage of ground water, perhaps somewhat more than usual in those sections of the city where the sewers pass through porous gravel strata. On the average the sewage represented a strength of about 120 gal. per capita daily. The results of the analyses of the sewage showed that, so far as the weights of each constituent of sewage per capita are concerned, it is very similar to that of London, England. It is much stronger than the sewage of the smaller Massachusetts cities, such as have been reported upon so carefully by the State Board of Health, and it is much more dilute than that of the manufacturing cities, such as Worcester, Mass., and Manchester, Birmingham, Leeds, Huddersfield and other English cities. The amount of suspended matter was about 215 parts per million, about such a sewage as that received at the Lawrence Testing Station in its early days, and about such as is received on the filtration areas at Clinton, Mass. It will not be necessary to record any more

of these details other than to say that it is not so strong a sewage as that at Brockton or some other places where the concentration, of course, is greater than at Columbus. But speaking generally, it may be considered to be a good representative domestic sewage, without unusual manufacturing wastes and with a normal amount of street wash from a clay country.

In Table No. 2 summarized data are presented showing the composition of the Columbus sewage, the various constituents being expressed in grams per capita daily. For the sake of comparison the composition of certain other representative sewages is also given.

In explanation of the data in this table it is to be stated that the records for the Columbus sewage involve the results of the analyses of more than 13 000 portions of sewage collected at frequent intervals during a period of about ten months. The average result approximates a 10 per cent. increase to the constituents found during a period of six weeks' drought, and during which time half-hourly samples of the sewage were collected on seven days of each eight-day period.

TABLE No. 2.

ESTIMATED QUANTITIES OF PRINCIPAL CONSTITUENTS IN GRAMS PER CAPITA DAILY OF THE SEWAGE OF COLUMBUS AND OTHER CITIES.

Constituents.	Average Columbus Sewage. (Combined System.)	Average Domestic Sewage from Small Mass. Cities. (Separate System.)	Average Domestic Sewage and Street Refuse. (London Combined System.)	Average Sewage for Manufacturing Cities. (Combined System.	Estimate Baltimore. (Separate System.)
Oxygen Consumed:					
Total	30	16.6	25	50	25
Dissolved	14	10.0	...	...	10
Suspended	16	77.0	...	...	15
Nitrogen·					
Total	14.4	11.6	13.0	13.0	13
Organic.					
Total	6.2	5.6	5.0	7.5	5.0
Dissolved	2.4	...	...	...	2.0
Suspended	3.8	...	...	...	3.0
Free Ammonia	8.2	6.0	8.0	5.5	8.0
Chlorine	32.0	16.0	24.0	44.0	16.0
Dissolved Matters:					
Total	410	97	157	268	..
Mineral	354	62	102	178	..
Volatile	56	35	55	90	..
Suspended Matters:					
Total	98	53	87	145	90
Mineral	51	12	41	69	35
Volatile	47	41	46	76	55
Total Solid Matters:					
Total	510	150	244	413	..
Mineral	407	74	143	247	..
Volatile	93	76	101	166	..
Free Carbonic Acid	13.6	...	...	...	..
Fats	19.1	...	...	...	19

Outline of Paper. — The writer has had numerous comparisons made of the Columbus data with other results from this country and abroad. Last winter such data were prepared as preliminary to the consideration of essential details of the problem at Baltimore, and more recently they have been reviewed in connection with a report, prepared in the office of the writer, to the International Waterways Commission upon sewage disposal at Chicago and vicinity.

The points presented in this paper are those most suitable for discussion, and are grouped under several headings as follows: I. Preparatory Treatments; II. Synopsis of Septic Treatment; III. Intermittent Sand Filters; IV. Contact Filters; V. Sprinkling Filters; VI. Sedimentation and Filtration of Effluents of Coarse Grain Filters; VII. Germicidal Treatments of the Same.

I. Preparatory Treatment of Columbus Sewage.

The tanks in which these tests were made were seven in number, each 40 ft. long by 8 ft. wide by 8 ft. in average depth. Various linear velocities were used, ranging from 0.2 mm. per sec. to about 13 mm. per sec., for periods of flow roughly ranging from about 0.3 hr. to about 24 hr. The number of intermediate periods was quite large, plain sedimentation having been studied on the basis of 6 and 8 hours' flow; septic tanks on the basis of 4, 8, 16 and 24 hr.; and chemical precipitation for an 8-hr. period with reference to coagulation by sulphate of alumina and by copperas and lime. The preparatory treatments also included the straining of the raw sewage through coke in circular tanks. One of the strainers was about 130 sq. ft. in area, representing about 0.003 acre, and the other was about 43.5 sq. ft. in area, or about 0.001 acre. The depth of coke in these tanks was about 18 in., and the size of the particles about 0.25 in. in average diameter.

These different preparatory treatments were studied more thoroughly from the analytical standpoint at Columbus than at any other place in this country, excepting Worcester, and probably more thoroughly than in any one place in Europe. As already stated, it is one of the strongest portions of the Columbus work, and it puts the question of preparatory treatments of sewage on a basis quite comparable with that which the various investigations on the Ohio and Mississippi rivers accomplished with reference to the preparatory treatment of these muddy waters preliminary to filtration.

Prior to its application to the various preparatory devices

the sewage was screened through 0.5 and 0.375-in. mesh screens. About 300 lb. of wet screenings, largely kitchen refuse, were removed from the sewage for each million gallons of sewage pumped. This is equal to about 0.2 cu. yd. per million gal., agreeing in general with results elsewhere, as, for instance, at Paris, France, where the screenings amount to 0.25 cu. yd. per million gal., and at Manchester, England, where 0.28 cu. yd. of screenings per million gal. are arrested by triplicate screens.

For purposes of discussion it will be most convenient to tabulate average Columbus data with representative data elsewhere and then give a résumé of the writer's views on the subject of preparatory treatments.

TABLE No. 3.

COMPARISON OF THE REMOVAL OF SUSPENDED MATTERS BY DIFFERENT METHODS AT COLUMBUS AND ELSEWHERE.

Kind of Treatment.	Tank Capacity. Hours Flow.	Tank Capacity. Linear Velocity. mm. per Second.	Percentage Removal. Suspended Matter. Total.	Suspended Matter. Volatile.	Total Organic Matter. Nitrogenous.	Total Organic Matter. Carbonaceous.
Columbus.						
Grit chamber (small),	0.3	10.0	22	19	10	6
,, ,, (large),	1.5	2.2	34	29	19	15
Plain sedimentation,	6.0	0.56	63	54	30	26
,, ,,	8.0	0.42	66	58	31	31
Septic tanks,	8.0	0.42	61	51	29	24
,, ,,	16.0	0.21	66	60	35	32
,, ,,	24.0	0.14	67	62	36	36
Chem. precipitation,	8.0	0.42	81	88	53	53
Coke strainers,	...	...	80	77	53	33
Cologne.						
Plain sedimentation,	0.31	40.0	61	59	..	..
,, ,,	0.62	20.0	70	68	..	..
,, ,,	3.10	4.0	73	71	..	..
Hanover.						
Plain sedimentation,	1.75	8.0	..	60	..	..
,, ,,	2.30	6.0	..	59	..	..
,, ,,	3.50	4.0	..	55	..	..

Résumé of Preparatory Treatments. — 1. The use of screens to remove the coarser suspended matter is practiced in many places abroad more effectively than in America, and it appears to be of demonstrated practicability to operate self-cleansing screens having an opening of at least 0.125 in. or about 3 mm.

2. There are some sewages, particularly those containing trade wastes with fibrous material, such as at Reading, Pa., where it may be practicable to use much finer screens, perhaps

from 30 to 80 meshes per linear inch. At Reading, after the sewage had passed through a screen with about 0.25 in. openings, it was found possible to remove about 20 per cent. of the remaining suspended matter by a revolving screen of brass cloth having about 80 meshes per linear inch; at Leeds, England, Harrison states about 10 to 15 per cent. was removed by a 30-mesh screen; Monti found, at Berlin, rather higher results as a rule when working with a 0.5 mm. (0.02 in.) screen following a 15 mm. screen. The practicability of the fine-mesh screen depends partly upon the success of self-cleansing attachments and partly upon the life of the screen itself.

3. In the ordinary American sewage there are some 50 parts per million of what might be called "colloidal suspended matter," the size of particles of which is so small that they are held in suspension by vortexual movement and are not responsive to the law of subsidence.

4. Plain sedimentation is the cheapest way to remove from sewage those particles too fine to be removed by the finest practicable screens and too coarse to be called "colloidal matter."

5. Plain sedimentation in the case of the ordinary American sewage will remove from 60 to 65 per cent. of the suspended matter, and 30 to 35 per cent. of the total organic matter.

6. A velocity of flow of about 1 ft. per min., or, as the Germans say, "4 mm. per sec.," for a period of about 6 hr., is ordinarily the economical limit to which plain sedimentation may be carried. The basins should be designed so that this velocity will not be materially exceeded at times when some of the basins are out of service for cleaning and when a portion of the contents of the other basins is occupied with sludge.

7. Plain sedimentation basins require the sludge to be removed about once in three weeks, on an average, depending on the season of the year, in order to prevent putrefaction in the deposited sludge from becoming too active. At Columbus the volume of this wet sludge (87 per cent. water) was about 5.75 cu. yd. per million gal. This figure would have to be increased in the case of trade wastes, as at Worcester, but reduced for purely domestic sewage.

8. The septic treatment, as taken up at length in a subsequent portion of this paper, consists of plain sedimentation with provisions for the accumulating sludge to undergo putrefaction without removal more often than once or twice a year. At times of unusual bacterial activity considerable sludge appears in the septic effluent unless unusual care is taken in arranging stop-

planks and baffle-boards. The average removal of suspended matter in the septic tank is slightly below that of plain sedimentation tanks, other things being equal. The accumulating deposits of sludge, as compared with those in plain sedimentation basins, cause the septic tanks to be somewhat larger than the plain sedimentation basins.

9. The removal of bacteria in sedimentation or septic tanks seems to approximate that of the total suspended matter as shown from the data obtained from comparatively small sewage settling basins and from numerous water settling basins. Bacterial growths of certain species within a septic tank frequently obscure this general statement, which is intended to apply especially to those bacteria originally present in the sewage, and particularly the pathogenic bacteria.

10. With the aid of chemicals it is possible to coagulate some of the colloidal matters and after settling to obtain a much better clarified effluent than is possible with sedimentation basins or septic tanks. For coarse-grain filters the resulting effluent has been found satisfactory in many places abroad, but experiences at Columbus, and apparently also at Worcester, indicate that the resulting hydrate requires a comparatively long period in which to precipitate and become removed, otherwise the surface of the sand filters may become clogged by it. In this regard the treatment of the effluent from chemical precipitation tanks is not unlike the experiences at Cincinnati and New Orleans in the filtration upon sand beds of clay-bearing waters which had been previously coagulated and more or less perfectly settled.

11. It seems extremely doubtful for American conditions whether the additional cost of coagulating chemicals and additional settling basin facilities would be compensated by a corresponding increase in rates of filtration either through sand beds, contact beds or sprinkling filters.

12. Coke strainers were found at Columbus to behave in a manner similar to experimental tests made at Lawrence, Mass., and with the operations on a larger scale at Gardner, Mass. During warm weather they afford the most effective means of preliminary treatment and at a cost which is not excessive if the coke or other material used can be burned under boilers. Their cost with the necessary covers to insure satisfactory results in winter necessarily limits their usefulness to a marked degree, if it does not preclude it.

13. None of these preparatory treatments will, by itself, give a non-putrescible effluent.

II. Synopsis of Septic Treatment.

The writer endeavors to state briefly in the following pages his conception of the septic treatment with sufficient clearness, it is hoped, to facilitate discussion and criticism on the part of other workers in this field.

Septic Treatment Defined. — The septic treatment is taken to mean a preliminary treatment of the sewage by plain sedimentation in basins of such size that sedimentation is carried to an economical limit and at the same time provision is made for the accumulation of sludge which will disappear in part by bacterial decomposition and so that the residuum requires cleaning out only once or twice a year. Such a basin with ordinary American sewages will hold on an average about an 8-hr. flow; it is by no means comparable with septic tanks holding several times this period of flow and in which there is likelihood or certainty of the flowing liquid itself becoming septicized. It is, of course, not possible for the liquid in a septic tank to remain above the putrefying sludge without the liquid containing more or less gas and particles resulting from putrefaction, some of which are dissolved and some suspended, particularly ferrous sulphide, which gives the effluent a dark appearance. It is practicable, however, to design and operate a septic tank so that its effluent will not be materially impregnated with toxic compounds. This feature is of controlling importance.

The septic treatment is essentially one to promote the economical and inoffensive disposition of the sludge removed from the sewage by sedimentation, and it is not to any practical degree helpful for subsequent filtration except in so far as the original sewage is clarified by physical means.

Screening. — As pointed out in the excellent paper presented to this section last autumn by Messrs. Eddy and Fales, the sewage should be well screened before entering the septic tank. The special purpose of this is to guard against the entrance into the tank of those suspended matters which mass together and which are raised from the bottom of the tank by gas evolution to the surface, where they are apt to remain as scum, thus escaping full bacterial action and liquefaction.

Linear Velocities. — It is believed that linear velocities should not be reduced at the outset to less than about 1 ft. per min. It is quite likely that a higher initial velocity and a progressive reduction would prove helpful within certain limits. The purpose of this, as in the case of screening, would be to prevent a great accumulation of suspended matters at the inlet

where they are inadequately treated by bacterial decomposition. If such cannot be avoided, it will be helpful to convert the first portion of the so-called "septic tank" into a grit chamber, cleaning the same perhaps at fairly frequent intervals, and as in the case at Birmingham, England, pumping some or all this sludge forward into the septic tanks to undergo subsequent bacterial action.

From the writer's standpoint the keynote of success in the septic tank is to enable the sewage to be clarified within reasonable limits and for the resulting sludge to be converted by bacterial decomposition to an inert and inodorous mass.

Seeding. — It is by no means certain in the mind of the writer that proper provisions as to the two preceding elements necessarily constitute success for a septic tank. It may be even more important that certain kinds of bacteria shall be present in the sludge under such conditions that the sludge is converted to an inert and inodorous mass. Whether the sludge is reduced to this inert mass or whether it is largely in a putrefying condition is a most practical test of the accomplishments of a septic tank. This is a marked difference between the well-known septic tanks, for instance, at Plainfield, N. J., and at Birmingham, England. It may be that the right kinds of bacteria will establish themselves sooner or later in the sludge of almost any septic tank, but the writer is beginning to doubt it. On the other hand, it may be that much more than hitherto can be done by the manager of the plant to facilitate the right kind of bacterial action. It appears to the writer that the custom of Mr. Watson at Birmingham, England, is a judicious one — that of allowing well and suitably inoculated sludge to flow into the bottom of each clean compartment of the septic tank before starting to fill it with sewage. Satisfactory seeding is thus assured. Data upon this subject should be made more precise and, in accordance with the writer's recent recommendations for Plainfield, N. J., this should be looked into most carefully, from the standpoint of both the bacteriologist and of the engineer. For the bacteriologist it is probably the biggest single problem on his hands in the field of sewage purification.

If it ordinarily takes from one to three weeks for septic action to establish itself, it will be readily seen that "seeding" with the proper kinds of bacteria should have an advantage from the standpoint of time as well as of ultimate decomposition.

Effect of Seasons. — Like all bacterial processes, the intensity of septic action is responsive to temperature conditions in a large

measure. This is well indicated by Table No. 4, showing the percentage by months which the gas produced from septic tanks at Worcester, Mass., is of the mean volume of gas.

TABLE No. 4.

PERCENTAGE WHICH THE VOLUME OF GAS PRODUCED EACH MONTH IN SEPTIC TANKS IS OF THE ANNUAL MEAN.

January	30	July	140
February	62	August	167
March	48	September	170
April	51	October	116
May	100	November	115
June	148	December	65

In all septic tanks there are numerous irregular fluctuations, but it is usual to see a ratio between maximum and minimum of about 5 or 6 to 1, as was the case at both Worcester and Columbus.

The questions of bacterial antagonism and other features than temperature are, of course, to be considered. But it is especially to be pointed out as explaining the wide discrepancies which have appeared in reports from various places upon the amount of sludge decomposed, and it makes a vast difference whether the data given refer to the cold winter months when the bacterial processes are working at a rate far lower than the average or whether they refer to the spring and early summer months. During the latter it is not unlikely that there are periods when the amount of sludge that is septicized will greatly exceed the total amount of sludge entering the tank for a time. These are the times when the winter accumulations largely disappear. Data as to the effectiveness of septic treatment in disposing of sludge should refer to the work of practically an entire year in order that the information may be utilized by others in a safe way.

Varying Treatment at Different Seasons — Flexibility of Design. — The writer is convinced that a septic tank should be designed with various compartments so that portions may be used from time to time and other portions temporarily thrown out of use if current analytical data should indicate that to be desirable. When the sludge in the tank is undergoing intense bacterial action, which usually occurs two or three times each year, arrangements should be made for throwing that tank out of service until the action practically ceases. Even with a set of tanks side by side these periods are not usually simultaneous.

Large amounts of decomposed sludge may be belched forth in the effluent with more or less unsatisfactory results in several ways, if care is not taken. After such a period of intense bacterial activity it would appear to be a logical time to clean the residual sludge from the tanks, but taking care to leave enough to "seed" the incoming sludge with the right kinds of bacteria.

The cost of division walls to provide the various compartments of a septic tank, by-passes and independent inlets and outlets is a wise investment.

This is especially true of works for small towns where the number of house connections made to a new sewer system is very small during the early life of the works. Without this flexible aspect of the septic tank it seems almost certain that trouble would result at the outset with a sewage which is very old even before it reaches the septic tanks.

Briefly stated, the septic tank ordinarily works very well; there are some exceptions, and it is now a question of bringing under control these exceptional conditions. This requires a better-designed tank than is now built, as a rule, and it calls for better management. If this process is fully satisfactory 350 days in a year, it is not to be forgotten as a last resort that there are many things, like the use of strong chemicals, by-passing the sewage around the septic tanks, etc., which can be done for 15 days and still have the net annual result very satisfactory.

Reduction of Sulphates. — At Columbus, owing to the exceedingly hard water with which the city is supplied, the sewage is highly charged with sulphates of lime and magnesia. In some instances elsewhere it appears that the sulphates are reduced by bacterial action to sulphides, in some instances sulphureted hydrogen being given off. This matter was studied carefully at Columbus and there was no indication of bacterial decomposition of sulphates. This is one of several observations upon which the writer predicates his thought that the "seeding" of septic tanks and the control of bacterial decomposition of sludge with suitable species is a matter upon which we have much to learn.

Over-Septicization. — The observations of the writer during recent visits to Europe lead to the conclusion that for the diluted sewages in America the septic treatment can be applied much more satisfactorily than for the strong sewages abroad. The sewages there are three to four times as concentrated as those in this country, and consequently to provide equivalent capacity for

the accumulation of sludge a tankage three to four times as great is required as with our weaker American sewages.

It is the belief of the writer that this set of conditions is far more favorable for American practice than is now realized. It means that the benefits of septic treatment may be secured with a far less likelihood of those complications which result from over-septicization, which might be defined as bacterial decomposition carried to a point where the sewage itself is highly charged with toxic compound resulting from such bacterial decomposition.

Production of Odors. — At Columbus no trouble was encountered with odors from septic tanks. It is not intended that this statement shall convey the idea that absolutely no odors of a sewage nature were to be found. That condition of affairs does not exist at any sewage purification plant, even an experimental one, if it is regularly operated for ten or twelve months. It means that no objectionable odors were noticeable, and this is the view point which should be held when this subject is considered in relation to large projects.

So far as the writer's personal observations are concerned, he has never noted any seriously objectionable odors at any of the septic tanks in practical operation in this country. He is aware, however, that such disagreeable odors were recorded at Worcester, Mass., and Pawtucket, R. I. Such experiences, however, have not been duplicated at Plainfield, N. J.; Saratoga, N. Y.; Mansfield, Ohio, and a number of other places where septic tanks of some size have been in service for a number of years. So far as he knows, no complaints have arisen in this country leading to actions at law so far as odors from septic tanks are concerned.

In regard to odors from septic tanks in England, there is a wide discrepancy in opinions recently stated in this country. Undoubtedly there are some septic tanks in England which, on account of their excessive size and other abnormal factors, have produced odors which may be properly called serious. On the other hand, the percentage of such instances is really very small according to the personal observations of the writer, who has three times visited England since the septic tank came into wide use. Two of these visits were during the summer months and one of them during the winter, shortly before the visits by a representative studying the problem for Paterson, N. J. The quotations in the Paterson report as to trouble from odors in and around septic tanks in England are, in the opinion of the writer,

almost certain to lead the inexperienced reader to incorrect conclusions on that subject.

To say that odors from septic tanks or from the aëration of septic effluents are objectionable for long distances, say perhaps, for 0.5 to 1 mile, is an over-statement which is not borne out by the fact so far as the writer has been able to ascertain by personal inspection and personal inquiry. In fact, the most striking feature with the connection of odors since the introduction of the so-called "biological method" has been their diminution. The abandonment of sewage farms in England has reduced the number of suits in court for alleged damages from this cause.

It is not the desire of the writer to claim that the odor factor does not exist in connection with septic tanks, but searching efforts made in England last September, at the end of an extremely hot period, convinced him that the statements made at the International Engineering Congress in 1904 at St. Louis, by Mr. H. Ross Hooper, M. Inst. C. E., engineer inspector of the Local Government Board of England, were practically correct.

"*Nuisances arising from Sewage Disposal Works.* — This may be said to be practically *nil*, unless due to the lack of intelligence on the part of employees. It may be said that the fact that many hospitals, asylums, recreation grounds, etc., often adjoin the works without any bad effect is sufficient to prove that they are not necessarily dangerous neighbors."

In connection with careful inquiries made into this and allied subjects for the Baltimore Sewerage Commission last year, it was concluded that a project involving septic tanks to dispose of the sewage of at least 600 000 people ought to be designed, built and operated so as to cause no objectionable odors at a distance of not more than 0.25 mile from the septic tanks. This conclusion is a fair statement of the case in the opinion of the writer.

In connection with the subject of odors it is to be clearly understood that reference is not made to septic sludge, but to odors from the tanks themselves and from the septic effluent, either with or without aëration. Undoubtedly there is much to be learned about the bacteriology of this subject and the writer looks forward in hopes of seeing the day come when these matters can be handled far more skillfully than at present. If no serious odor at all is found at the largest installation in the world, at Birmingham, England (and it is claimed by some that this is due

partly to waste iron liquors and partly to the right kind of putrefactive bacteria), who can say that later on these conditions cannot be artificially provided elsewhere without difficulty?

Covered Septic Tanks. — In a majority of instances the writer has advised the use of uncovered septic tanks, although for climatic reasons he has favored the use of covers for some cases.

With properly designed septic tanks, so that the operation may be adjusted within a fairly wide range of conditions, the writer is still of the opinion that covers, so far as odors are concerned, are not necessary with the weak American sewages.

With strong English sewage, particularly those from which sulphate reductions occur, there is a good deal to be said in favor of covers, as is well summarized by Mr. George R. Strachan, M. Inst. C. E., the distinguished sanitary engineer of London, in his report on the Toronto problem last summer as follows:

"There can be little doubt that the processes of septicizing go on as efficiently in an uncovered tank as in one that is covered when once the scum has formed and remains intact. The Toronto tanks were to be covered for climatic reasons, and, therefore, the issue does not, strictly speaking, arise in this case, but it may be well to state that the odors from open septic tanks have been abominable in several cases of nuisance I have investigated. There are open tanks without offense, such as those at Birmingham, but the sewage there is much mixed with trade wastes, which seem to give it an impunity in this respect. In every case of open tanks I know of where the sewage is domestic, offense is present and often in a pronounced form. The trouble arises in three ways. There is first and continuously the ebullition of new septic sludge through vents in the scum, which gives off putrid odors when drying in the air and sun. There is second, and frequently, the wetting of the scum by rain and the subsequent bad odors during evaporation and absorption. Then a third and less frequent offense is caused by the wind compressing the scum into a more solid mass and leaving a part of the septicized sewage exposed."

For American conditions where it is not too cold the writer would prefer to guard against odors with an open septic tank of a flexible design as heretofore indicated rather than with a covered tank built like many of those in use in England. In fact, it is only fair to state that many septic tanks abroad are merely adaptations of former chemical precipitation tanks.

Disposition of Septic Sludge. — This is the real problem

with the septic process under American conditions, according to the writer's experiences. At Birmingham, England, where this process is best carried on, the sludge is an inert humous mass, practically inodorous. It is usually applied to land in depths of about 8 to 10 in. and will usually evaporate to about one third of that thickness within a few months. This sludge will not support vegetation. The idea prevails among many that sludge from the Birmingham septic tanks requires to be plowed in. This is not so. It is a mere coincidence that the plowing occurs. With a large area of land they naturally have no desire to get any portion of it treated with so thick a layer of sludge that it is no longer responsive to agricultural pursuits. Naturally they apply this sludge in very thin layers and plow it in with a steam plow in order to mix the same very thoroughly.

The sludge from grit chambers at Birmingham is by no means free from odors, due to the fact that it contains much organic matter which has not passed through the putrefying stage. It is very interesting to note that this fairly fresh sludge from the grit chambers is frequently covered with a layer of septic sludge in order to guard against odors when applying the former material near roads, etc.

In most cases in America the trouble with septic sludge has been that it resembles the grit chamber sludge of Birmingham and not the septic sludge at that place. The real problem ahead of us is how to correct this, because, if this is done, it insures an extremely economical means of disposing of one of the most awkward elements of sewage purification by applying the residuum to land and allowing it to air-dry.

As to the amount of sludge from septic tanks, it was estimated at Columbus (combined sewers) to be about 2.68 cu. yd. per million gallons of sewage treated. Two cubic yards were used in the Baltimore estimates with a separate system of sewers. This corresponds roughly to a reduction in the weight of total deposited matters of about 50 per cent. on an average. In the winter the reduction is far less than this, but in the spring and summer it is much more.

At Columbus provision is made for disposing of septic sludge either upon land or upon the Scioto River at times of flood flows. The latter procedure is, of course, quite unusual and one which could not be carried out at many places elsewhere owing to the lack of similar conditions. It may be stated here that this disposition is by no means so incompatible with sound hygiene as would appear at first sight. If our present informa-

tion as to the longevity of disease germs in sewage counts for much it shows that there is not great danger in this sludge, — much less, in fact, than in fresh sewage which enters the river at Columbus and elsewhere at each storm when the combined sewers overflow.

While the disposal of sludge at Birmingham without any attending bad odors is a chief step in advance accomplished by Mr. Watson, it is very gratifying to note that he does this at a cost of only five cents per cu. yd., or 10 to 15 cents per million gallons of ordinary American sewage.

Separate Tanks for Septicization of Sludge. — Several schemes have been proposed relative to the withdrawal of sludge from settling tanks in order that septicization of the sludge may occur in separate tanks from those through which the main body of the sewage passes. It is claimed for this procedure that it aids in reducing odors in the settled liquor as applied to filters, especially those of the sprinkling type.

Obviously it would add much to the cost of operating sewage works under ordinary conditions as to arrangements. The cost of construction would also be materially increased if the secondary tanks are large enough to store the accumulation of sludge during the cold season.

It seems to the writer very doubtful whether any advantage corresponding to the increased cost would result from this scheme either as to odors at the tanks themselves or of the settled liquid as applied to the filters in the event that the effluents from the settling tanks and the separate septic tanks are united. The reason is that if a given amount of organic matter is subjected to bacterial decomposition and the same bacterial results are accomplished, it seems an obvious proposition that the by-products would be the same as they are proportional to the amount of bacterial work accomplished.

There might be some advantage if the effluent of these septic tanks were to be treated in, say, contact filters rather than on sprinkling filters. This is the only way in which this scheme appears meritorious to the writer.

It may be that those favoring this arrangement intend to dispose of the sludge without having it well septicized. So far as application to land is concerned, the writer is opposed to decomposing as compared with decomposed sludge.

Hygienic Efficiency. — It is the writer's view, even in places where bacterial growths occur in septic tanks so that the numbers in the effluent exceed those in the influent, that the hygienic

efficiency of the septic tank in round numbers approximates the removal of the total suspended matter. This, of course, refers to the bacteria present in the liquid entering the tanks and especially those species of a pathogenic nature which do not grow within the tanks.

There is a good deal to support the thought that the removal of bacteria in septic tanks from a hygienic standpoint is considerably in excess of the removal of total suspended matters. This brings up the question of bacterial antagonism, which requires considerable study to establish its practical significance with regard to septic tanks.

Bacteriologists have quite a task before them to put matters upon this score in definite terms, and it is none the less important because so many of the data are obscured by growths, the significance of which is not fully understood.

III. Intermittent Sand Filtration.

At the Columbus Testing Station more of the processes included intermittent sand filters as a portion of the method of purification than any other style of filter. The results obtained were in general harmony with the long and well-known studies and experiences in Massachusetts. There was nothing very new or startling learned from the sand filter tests, although the advantages of giving the sewage a preparatory treatment were set forth in perhaps a more comprehensive and comparable manner than elsewhere.

It was found that plain sedimentation on the whole was rather the best preparatory treatment, although coke strainers during the warmer season of the year were found to be even more satisfactory. Septic treatment was of no advantage as compared with sedimentation, and there were times when there was something of a disadvantage, owing to the sludge belching forth with the effluent. In practice this could be largely reduced in a plant well built and well managed.

As to chemical precipitation, references have already been made to the experiences encountered similar to those of Mr. Eddy at Worcester, namely, the appearance of the coagulated masses upon the surface of the beds. This led to undue clogging and could be avoided only by the use of basins of larger capacity. This would increase the cost to a point where this method would hardly be of much use.

There has been recently a good deal of comparative discussion of sand filters for sewage purification, some of it warmly

advocating the process and some of it otherwise. The Columbus work from a broad practical standpoint is chiefly of interest because it has shown that at a locality where sand could be laid down in place for about $1.25 per cu. yd., yet sand filters of artificial construction cannot be economically built in comparison with the more modern contact filters and sprinkling filters. The Columbus sand filters were estimated to cost $8 940 per acre complete, but exclusive of land and engineering.

The same conclusion was reached by the advisory engineers at Baltimore in their report last spring. While there is much good sand within a moderate distance of the city, so much of it is in very thin strata, and so much is mixed with clay, it was found cheaper to build artificial beds, the cost of which was estimated at $6 350 per acre, including engineering, but excluding land. This latter project was found to be more expensive than sprinkling filters followed by sand filters for a finishing treatment.

Still another illustration of the cost of sand filters is afforded by the recent report of Messrs. Hering and Fuller to the International Waterways Commission on the cost of purifying the sewage of an assumed population of 1 200 000 people on the Calumet area south of the City of Chicago. These figures are summarized as follows:

TABLE No. 5.

	Kind of Filter.		
	Sand.	Contact.	Sprinkling.
Construction cost, with appurtenances	$11 063 000	$11 787 500	$9 257 500
Annual operating expenses capitalized at 5 per cent	17 320 000	11 020 000	8 380 000
Total	$28 383 000	$22 807 500	$17 637 500

In each of the above projects are included intercepting sewers, pumping stations and force mains connecting with the septic tanks and filters.

Notwithstanding the above, the writer is clearly of the opinion that the intermittent sand filter, which has served and is serving such a useful purpose in Massachusetts, is by no means an institution of the past. Its efficiency is high, and where suitable areas of porous sand are near at hand it is frequently the cheapest method that can be availed of, especially for towns and cities not exceeding 30 000 or 40 000 population. For large communities the intermittent sand filter does not seem to

be so applicable, owing to lower operating expenses for large filters of other types.

With sewage which has been screened and settled for perhaps 0.5 hr. it was found that a rate of 100 000 gal. per acre daily was about the full normal load. The test filters at Columbus contained 3 ft. of Lake Erie sand of an effective size of about 0.25 mm.

The above load corresponds to the sewage of about 800 persons per acre. This is closely in accord with Lawrence data, which the writer computes from the amount of applied nitrogen as given by Mr. H. W. Clark in the 1904 Report of the Massachusetts State Board of Health, pp. 212–15, and on the assumption that each person at Lawrence contributes 13 g. of nitrogen daily. These Lawrence data refer to the outside filters and not to the small indoor tanks.

TABLE No. 6.

COMPUTATIONS OF LAWRENCE SAND FILTER LOADS, 1904.

Number of Filter.	Kind of Material.	Effective Size in mm.	Years in Service.	Av. Gals. per Acre Daily.	Av. No. Persons per Acre.
1	Coarse sand	0.48	17	61 110	730
2	Fine sand	0.08	17	31 700	380
4	Very fine sand	0.04	17	20 200	260
6	Sand and gravel	0.35	17	49 200	630
9	Medium sand	0.17	14	60 300	785

Such rates as indicated by the above are not wholly in accord with some of the data of sand filter plants in actual practice in Massachusetts. Where the rates in practice are recorded as much higher it is believed that they represent only a short period of loading and that filter extensions must soon follow. Other cases in Massachusetts are to be found where the rates in practice are lower than necessary. In this connection it is of interest to compare the data from the 1903 Report of the Massachusetts State Board of Health.

TABLE No. 7.

MASSACHUSETTS SAND FILTER LOADS, 1903.

Place.	*Population.	Place.	* Population.
Andover	950	Natick	360
Brockton	1 160	Pittsfield	605
Clinton	425	Southbridge	305
Concord	365	Spencer	320
Framingham	375	Stockbridge	220
Gardner (old)	1 310	Westboro	750
Gardner (new)	2 000	Worcester	1 390
Marlboro	840		

* Population connected with sewers for each acre of filter.

At Lawrence the clarification of the sewage led to higher rates, as indicated in Table No. 8, computed by the writer for his paper on "Sewage Disposal in America," for the International Engineering Congress.

TABLE No. 8.

Kind of Preparatory Treatment.	Years Tested.	Rates of Filtration through Medium Sand. Gal. per Acre Daily.
None	1891–1902	58 688
Filtered through gravel	1892–1897	503 030
Sedimentation	1893–1897	177 049
Coke strainer	1894–1899	236 587
Chemical precipitation	1893–1897	188 065
Septic treatment	1898–1902	208 024
,, ,,	1898–1902	184 235
,, ,, *	1899–1902	212 253

* Aërated.

At Columbus it was found that sedimentation and septic treatment allowed rates to be used satisfactorily up to 250 000 gal. per acre daily and even a little higher. As the filters grow older it is quite debatable whether the cost of operation during the winter would not make lower rates more advantageous in practice.

The question of balancing rates of filtration and operating expenses to give the most economical results for large plants in practice is one upon which present evidence is not as definite as desired.

Another question is whether sedimentation enables the rate to be tripled, as compared with the requirements for unsettled sewage, and thus keep the applied suspended matter the same; or whether it permits the rate to be increased 50 per cent., thus keeping the applied organic matter a constant.

IV. Contact Filters.

The contact filters which were tested at Columbus were 5 ft. in depth. The size of the material ranged from 0.25 to 2 in. They were found to be capable of giving a non-putrescible effluent when the applied sewage had been clarified by sedimentation or septic treatment at a rate of from 600 000 to 700-000 gal. per acre daily on an average.

Comparing these conclusions with other experimental data in this country as well as other experiences in practice in this country and abroad, there seems to be a substantial harmony. For a contact filter of the ordinary depth of about 4 ft.,

it seems hardly practicable to figure on a net average rate of more than 500 000 gal. per acre daily. For short periods this rate, of course, can be much exceeded.

The most striking feature of the American experiences with contact filters as compared with those abroad is that the rate of purification seems to be substantially the same regardless of the marked difference in the strength of the sewage. This constitutes one of the essential differences between contact filters and sprinkling filters. It also furnishes an excellent basis for testing the validity of numerous theories as to the operation and accomplishments of contact filters.

At Columbus it was found that the contact beds arranged for double treatment gave more satisfactory results per unit area of total filtering surface than where there was only single contact. The difference was not striking, however.

Some attention was given at Columbus to the question of operating contact filters from below with a special view to operating sprinkling filters temporarily in this manner during periods of very cold weather. The procedure was found to be practicable, although, of course, in the case of double contact it is far better than with single contact. In the latter instance the sewage which last enters the filter leaves first and hence is not wholly purified. This feature is overcome with the double contact.

The filling of contact filters from below is, of course, not by any means a new story. It was studied many years ago at Hamburg, Germany, by Professor Dunbar. In the opinion of the writer it has more practicable merit than it has been credited with up to this time. It is being regularly used at Langensalze, Germany, and at Hampton, England, with apparently satisfactory results.

It is the most successful way there is of keeping a sewage obscured from view until it has reached the non-putrescible state. It also gives an exceedingly high quality of effluent when the double contact filters are followed by a third filter or strainer of sand or some other material.

The writer recently recommended this treatment for the sewage of the Soldier's Home, Togus, Me., where a high grade of effluent was sought, not only during summer conditions, but also during the winter, when it would have to contend with both heavy snows and low temperature, and also with comparatively small stream flows in the brook which receives the effluent.

The contact filters were shown 5 ft. in depth and provided with a false floor, substantially as in the case of sprinkling

filters. It is not intended that the surface of either the primary or secondary contact filter would ever be covered with sewage. In fact, during the winter it will be the purpose to fill the contact filters from below only to within about 1 ft. of the surface. This effluent, which will be non-putrescible and distinctly turbid, will be settled for a very short time and then passed through a sand filter, which should uniformly produce an effluent of brilliant appearance and high-grade purity.

The contact filter has served a useful purpose where sand filters could not be advantageously installed and will, no doubt, continue to do so in the future, especially in those instances where it can be used without pumping and where pumping would be required for sprinkling filters.

V. Sprinkling Filter.

The most important single point learned at Columbus was probably that of the practical accomplishments of sprinkling filters under such a northern climate during the winter season. With fixed sprinkler jets it was found at a temperature of 10 degrees below zero that there were no complications as to clogging with suitably designed orifices and that a considerable number of days might elapse under such conditions without the amount of frozen sewage accumulating to a degree interfering seriously with the results of filtration. Compared with previous views held in this country, this was a great step in advance, as it meant that the sprinkling filter, with its ability to produce a non-putrescible effluent at rates of filtration three to four times as great as in the case of contact filters, was a practicable proposition.

Method of Dosing. — It is unnecessary to enter into this subject at length, as its features for the works adopted at Columbus have been described in the *Engineering Record* of December 30, 1905, and the details of the sprinkling nozzle have been set forth by the designer, Mr. John H. Gregory, in the Proceedings American Society Civil Engineers, September, 1906. The use of this large orifice, above which is placed an inverted cone, is a marked improvement as compared with the small orifices more generally used in Europe and which involve considerable expense for cleaning. After having visited practically all of the experimental stations in this country and Europe and representative plants where each method of distribution is used in practice, the writer is clearly of the opinion that the Columbus method of application of the sewage to sprinkling filters is by far the best and cheapest.

The use of the large orifice for the sprinkling nozzle at Columbus arose from the plan of using a rate of 4 000 000 gal. per acre daily for the sprinkling filters during the time that the latter were actually in service. It is perfectly feasible to use such a large orifice or even a still larger one with the aid of a dosing tank or reservoir in which to store up the influent for a number of minutes and from which it is then discharged to the sprinkling filter through such orifices. In the sprinkling filter plant now under erection at Reading, Pa., the writer has advised the use of a dosing tank which would require about a ten-minute interval for filling and emptying. Accordingly, during each ten-minute interval the liquid would be applied through the nozzle under a range of head from the maximum to the minimum. This would cause, during each ten-minute interval, about 80 per cent. of the area of sprinkling filter surface to be covered with spray in a substantially uniform manner. Practically speaking, this is very nearly perfect, when consideration is given to the marked influence exerted by a slight wind on this fine spray.

Filtering Material. — The tests at Columbus were conducted with material of a size ranging from about 0.5 to 2 in. The writer's observations at various works in Europe have led him to conclude that this is too fine in order to maintain a vertical circulation of air at all times. The actual mean diameter of the particles ranging from 1 to 2.5 or 1 to 3 in. is considered preferable. The finer material gives a somewhat better effluent than the coarser beds, other things being equal, but the difficulty in getting ample air into the pores of the finer material and the cost of cleaning the same in the event of clogging, causes the writer to lean much more strongly to coarse material than he did during the Columbus tests.

As to the depth of material, the 5-ft. beds at Columbus are undoubtedly a minimum. They will allow a non-putrescible effluent to be obtained, but for reasons of economy and efficiency it is desirable to make the filters somewhat thicker. Generally speaking, the writer favors a depth of 6 to 7 ft. At Baltimore a depth of 9 ft. was recommended under conditions where it was urgent to secure the highest form of bacterial removal.

In the recent report made to the International Waterways Commission for the disposal of sewage of the Calumet area near Chicago, a depth of 7 ft. was advised for the sprinkling filter project. The reason of this was to a considerable degree due to

the desirability of making the area liberal for meeting the extreme weather conditions in winter. At such critical times it is clear that the best investment of a certain sum of money does not lie in very deep beds. Just exactly how all these questions of depth of bed, size of material, etc., will be ultimately adjusted can only be told after more experience on a large practical scale has been obtained.

Retaining Walls. — In the paper which the writer presented to the International Engineering Congress in 1904, reviewing the status of sewage disposal in America, it was suggested that one of the advantages of sprinkling filters was that they needed no retaining walls. As soon as the writer had occasion to figure upon the details of various projects it was quickly ascertained that it is cheaper to build retaining walls than it is to increase the floor and false bottom and filtering material sufficiently to create an angle of repose for the filtering material. In other words, the " heap-of-stone " theory cannot be taken too literally, as it is really cheapest to build a concrete basin and fill it with material.

One of the principal reasons why the writer mentions this point is the possibility of using sprinkling filters temporarily as contact filters. Mr. John H. Gregory, in designing the main works at Columbus, has arranged that this might be done whenever desired during extreme winter weather and when there might be danger of getting too much frozen sewage on the surface of the filters.

There is another set of conditions where sprinkling filters might to advantage be operated temporarily as contact filters, namely, in adapting them to a community which is just being provided with sewers and where the number of sewer connections is at first very small. It is quite feasible that the sewage might become over-septicized before reaching the sewage works and thus temporarily give unusually bad odors. The idea of operating sprinkling filters as contact filters under such circumstances as these was included in the project recently recommended by the writer for the borough of North Plainfield, N. J.

Odors. — The distribution of sewage in the form of spray naturally intensifies any tendency towards bad odors. It is the writer's practice and endeavor to keep sprinkling filters at least 0.25 mile away from roads and buildings. Under this condition he has no fear that a well-built and well-managed plant will give trouble from odor, notwithstanding the occasional opinion expressed to the contrary.

Capacity. — As a result of the Columbus tests it was concluded that with a sewage corresponding to about 120 gal. per capita daily, and including street wash, a rate of filtration of 2 000 000 gal. per acre daily on an average was feasible. The main works at Columbus are designed substantially on this basis, although a portion of the present city will be on the separate system. It is stated in round numbers that a 10-acre plant will serve a population of 200 000 people. This makes a load of 20 000 people per acre on a filter bed 5 ft. deep, or 4 000 people per acre-ft.

In England, 1 000 000 imperial gal. or 1 200 000 U. S. gal. per acre is the ordinary load which corresponds to about 30 000 people for a bed which is usually 6 to 8 ft. thick. There are instances, such as at Accrington, where an area of less than one acre of beds averaging about 8.5 ft. in thickness are taking care of the sewage of about 50 000 people.

One of the most characteristic features of the sprinkling filter as distinguished from the contact filter is its ability to operate at various rates with sewage of different strengths but which bring about the same load as to organic matter, other things being equal. In other words, here is a style of filter which will take care of the sewage of as many people per acre with the dilute American sewage as it will with the concentrated European sewage. This is an advantage, the significance of which is not yet fully appreciated. It is hardly feasible yet to name the standard load per acre-ft., as that depends largely upon questions of street wash, trade waste and climatic conditions, as well as upon the question of whether it is desired to secure a high removal of bacteria or simply secure a non-putrescible effluent. During fairly warm weather there seems to be no trouble whatever in operating sprinkling filters at rates of 6 000 people per acre-ft., but during the winter these rates must undoubtedly be lowered materially for northern climates. In the recent report to the International Waterways Commission, Messrs. Hering and Fuller applied a factor of safety resulting in a layout with one acre of sprinkling filter surface 7 ft. deep for each 15 000 population. If such a plant were operated it is probable that half of the sprinkling filter would do the work during nine or ten months of the year.

Cleaning. — A notable characteristic of the sprinkling filter, as is well-known, is its self-cleansing properties. This necessitates a false bottom with ample slopes both to the floor and to the main collectors. With reasonable care it is believed

that a sprinkling filter will operate under good management for ten or fifteen years without cleaning. Such low operating expenses when capitalized and added to the construction cost form one of the chief reasons why these recent sprinkling filter projects have made such a favorable showing in comparison with both contact filters and sand filters.

Already in several places in Europe filters have been operated regularly for over seven years without cleaning. It does not follow, however, that they do not require attention to prevent clogging. In the opinion of the writer the sprinkling filter is a much more efficient institution when operated intermittently than when operated continuously. Just what the best degree of intermittency may be can hardly be told now as it depends a great deal on the size and character of the filtering material. At Columbus, Mr. Geo. A. Johnson thought that it was highly desirable to provide long periods of rest. They were undoubtedly helpful in causing the unloading of stored material, but whether they were necessary or not under regular conditions of practice cannot now be told.

Bacterial Removal. — The removal of bacteria by the sprinkling filters at Columbus was about 70 per cent. of those in the applied liquid and it is estimated to be about 90 per cent. when compared with the bacteria in the original sewage. These results obtained with 5-ft. beds would be much higher with deeper beds. The Lawrence data indicate that there would be a total removal of from 95 to 97 per cent. with 10 ft. filters. Although the latter filters would also give higher nitrification, it is debatable whether this is the best way to secure such removal of bacteria.

VI. Sedimentation and Filtration of the Effluents of Coarse Grain Filters.

So far as the writer knows, there is no instance in this country where the effluent of contact filters has been settled. When the filters are filled from above the effluent is usually sufficiently well clarified to make that treatment unnecessary.

In the case of contact filters filled from below it is believed that it might be advantageous under some circumstances to adopt a clarification of the effluent by sedimentation substantially as is required with sprinkling filters. The sedimentation of the effluent from double contact filters filled from below, and its subsequent filtration through sand, is a feature of a disposal plant recently designed by the writer for Madison, N. J.

Successful sprinkling filters produce an effluent in which the suspended matter on an average is fully as great as in the influent. The amount of suspended matter varies widely, due to the irregular elimination by the filter of the matters removed from the sewage in the form of films around the filtering material. Some of the fine colloidal particles pass directly through the filter and others are retained upon the sticky surfaces of the material. Particularly after resting and drying, these films become detached, and as has already been explained in connection with the cleaning of sprinkling filters, one of the chief characteristics of this type of filter is its ability to convert fine suspended matter in the influent to coarse suspended matter in the effluent.

Where non-putrescible results alone are desired it is sufficient to settle the sprinkling filter effluent for from one to two hr. in order to deposit those particles of a fairly coarse nature. Columbus data indicate that on an average such deposit amounts, under local conditions, to about 1 cu. yd. per million gallons. The other suspended particles in the sprinkling filter effluent are so fine that they cannot be removed by subsidence.

Test of Putrescibility. — In passing it may be stated with reference to putrescibility that it is the opinion of the writer that field tests made at the works at frequent intervals to show whether or not the effluent is putrescible are generally more helpful than complete analyses of the effluent made at intervals of once a month or so. As a guide to the man in immediate charge of such a plant there is no comparison between the aid derived from the two styles of testing.

After examining carefully the various methods used in the laboratories in this country and in Europe, it is the writer's opinion that the present form of the putrescibility test applied under the direction of Dr. Scudder in the Mersey and Irwell valleys is the simplest and most practicable. It consists in mixing equal volumes of the effluent and of well-shaken tap water and allowing the same to be incubated at a fairly high temperature for 24 hr. A qualitative test is then made for dissolved oxygen. If oxygen is still present the result is considered satisfactory.

Dr. Scudder tells the writer that this has done a great deal of good in the hands of local managers of sewage works, as it not only develops self-confidence, but stimulates greatly the interest of the local management in seeing that the results meet a practical test which they themselves can both understand and apply. The beneficial aspect of this state of affairs is great

in comparison with conditions surrounding the results of analyses made at a central laboratory at more or less irregular intervals and the results of which when received some days later are viewed in many cases by the local management with feelings of uncertainty.

Improved Bacterial Results by Filtration. — At Columbus a number of tests were made to show the improvement in sprinkling filter effluent resulting from filtration through sand following sedimentation in intermediate basins. The data can be regarded only as suggestive for the most part, as the facilities were not well adapted to testing this feature very satisfactorily. The extended data obtained by Mr. H. W. Clark at Lawrence on this subject afford a much better index.

A review of all the data bearing upon this subject in connection with the Baltimore problem last spring led to the conclusion that sand filters 3 ft. deep could operate at about an average rate of 750 000 gal. per acre daily. Such an effluent would contain ordinarily only about 1 per cent. of the bacteria in the applied sewage and would also be practically free from turbidity.

In connection with the Baltimore proposition the writer gave considerable attention to the use of mechanical filters for the final purification and clarification of the sprinkling filter effluent. With mechanical filters built in a plain, substantial way about like the best mill filters, it was found that the total cost, both operating and capital charges, would be the same for mechanical filters as was estimated for sand filters, if the sprinkling filter effluent could be satisfactorily coagulated with sulphate of alumina when applied at an average rate of 2.125 gr. per gal.

Various tests on a small scale were made by a number of workers to ascertain the amount of required coagulant and the results showed such a wide range that the project was decided by the advisory engineers to be too indefinite for recommendation. The extreme range was from 1.25 gr. of sulphate of alumina, required for several effluents tested by Mr. A. E. Kimberly in Ohio, to about 3.5 gr., required for settled sprinkling filter effluent by Mr. H. W. Clark at Lawrence.

How far the use of copperas and lime might bear upon this question of cost of coagulating sprinkling filter effluents for use in mechanical filters is not yet clearly understood. Some preliminary tests in this direction were made, but as a rule it was found difficult to get the iron separated out as a hydrate.

VII. Germicidal Treatment of the Effluent of Coarse Grain Filters.

The supplementary treatment proposed for Baltimore by means of sand filtration is estimated to cost $3.91 per million gallons for operating and capital charges. On the evidence available at that time it was considered that there was no reliable means of treating the effluent of sprinkling filters with a germicidal chemical to give results equal in efficiency to the sand filtration treatment and at as low a cost.

Within the past few months there have been a number of important developments in several branches of the field of germicidal treatment. The writer will refer briefly to a few points to facilitate discussion.

Ozone Treatment. — So far as the writer knows, the use of ozone has never been seriously considered in connection with sewage effluents. In fact, for water purification purposes there have been two serious drawbacks to its tentative use in Europe, one being the irregularity of its production by the best devices, and the other the cost of its production. Recently the United Water Improvement Company at Philadelphia, Pa., has claimed that recent discoveries by members of its staff enable from 65 to 80 g. of ozone to be produced per kw-hr. This is four to five times as much ozone as could be produced per kw-hr. as previously figured. If this is true it has an important practical significance.

Test devices are now about completed by which the use of ozone for purposes of sterilizing and bleaching the Croton water may be thoroughly studied at the testing station of the Water Department of New York City at Jerome Park Reservoir. The essential data as to the production of ozone will no doubt be fully developed here in due time.

Copper Sulphate. — This is still being studied by the Bureau of Plant Industry of the United States Department of Agriculture. So far as is known there are no data indicating that sewage effluents can be sterilized for less than $5 per million gallons. In fact, the studies by Mr. Geo. A. Johnson at Columbus on this subject seem to be the most extended. They indicated some doubt as to whether or not this price will give adequate treatment.

Chlorine and Hypochlorite. — Two interesting papers have recently appeared upon this subject, namely, "The Prevention of Bacterial Contamination of Streams and Oyster Beds," by W. Pollard Digby, F. S. S., A. M. I. Mech. E., A. M. Inst. C. E.,

and Henry C. H. Shenton, M. S. E., read before the Royal United Service Institution, December 3, 1906, and "The Sterilization of Sewage Filter Effluents," by Messrs. Phelps and Carpenter, in the last number of the *Technology Quarterly*, which was published about a month ago (January, 1907).

These papers contain many very interesting and suggestive statements as well as results of important original work.

It appears from this evidence that 50 parts per million of free chlorine when applied to a settled sewage effluent will produce sterility and that an application of 5 parts per million of free chlorine acting for a period of 2 hr. will remove materially more than 99 per cent. of the total bacteria and will practically eliminate intestinal bacteria as indicated by tests for B. coli.

Mr. Digby, who was connected as electrical engineer with the company which has developed the Woolf process in this country and England, has recently made important discoveries as to electrolytic cells for the decomposition of solutions of salt. Estimates of the cost per pound of available chlorine are given in the paper of Messrs. Digby and Shenton as ranging from 8.7 to 9.7 cents with electricity at 2 cents per kw-hr. and salt at $4 per ton.

Messrs. Phelps and Carpenter indicate in their paper that available chlorine can be manufactured for about 1.3 cents per lb., according to certain experiences in large paper mills using the McDonald electrolytic cell. Power is figured at 0.6 cents per kw-hr. with a production of 0.46 lb. of chlorine per kw-hr. On this basis it is stated that it would cost about 85 cents per million gallons to treat sewage effluents with 5 parts per million of free chlorine. It is believed that this figure is far below that which would be the actual cost in practice at most places, especially for plants of small or moderate size. In the first instance, coal is taken at $2 per ton, which is possible only in and near the coal regions. In the second place, the figures of Messrs. Phelps and Carpenter should be increased for charges for labor, both for generating power and for the application of the chlorine to the sewage effluent, interest on the capital investment for both power plant and treatment plant as well as the usual items for repairs, renewal and depreciation.

It is believed that the Digby and McDonald electrolytic cells note marked steps in advance along the line of improvements required for certain types of sewage disposal problems.

DISCUSSION.

Mr. R. Winthrop Pratt. — Mr. Fuller has in his paper mentioned the relation the State Board of Health has borne to the Columbus experiments. This Board has, from the beginning, kept in close touch with the city of Columbus in the various preliminary investigations and proposed schemes for sewage purification, and has endeavored to assist, educate and interest the citizens in regard to the problem. The unanimity of opinion among the people of Columbus as to spending the sum of $1 200 000 for sewage purification works was shown by the fact that this money was raised by popular vote requiring two-thirds majority.

The work which has been done at the Columbus Sewage Testing Station has been of great value to the State Board of Health in enabling it to point out to local officials the seriousness and importance of the question of sewage disposal, and to induce such officials to make suitable preliminary investigations of their own problems before spending any money in construction. While the experiments were in progress delegations from nearly every town in the state which was interested in the matter of sewage disposal made visits to the testing station.

After the experiments were concluded it was urged by some persons that it would be very desirable for the State Board of Health to continue the work at this station, and a movement was talked of to obtain the necessary legislation to enable this to be done. As the amount of money which the legislature would appropriate for work of the State Board of Health was known to be quite limited. it was thought on maturer consideration that the interest of a larger number of people would be served by making a series of studies of the various existing plants which are in operation in the state of Ohio.

With this in mind the Ohio legislature, in the spring of 1906, passed a bill directing the State Board of Health to make an investigation of the construction, methods of operation and the efficiency of all public water purification works and sewage purification works in this state, and made an appropriation to pay for this work. The investigation directed by the act was started immediately. Three additional assistant engineers were placed in the engineering department. Mr. A. Elliott Kimberly, formerly of the staff of the sewage testing station, was appointed special assistant engineer to conduct the field investigations relative to the various sewage plants.

The work under the above act up to date has proved of very great value. Not only has much information been obtained relative to the behavior of different types of sewage plants under different local conditions, but the officials in charge of the plants have become interested in the work and in several cases have improved and even remodeled their works, thus putting them on an efficient basis, whereas previous to our investigation they were useless. At four of the plants, where filters of coarse grain material are in use and where the practical test for efficiency is a non-putrescible effluent, we have arranged with the superintendents to make incubation tests daily of the effluent, and to keep full records of the principal features of operation of their plants.

The report on this work, including the water purification investigations, will be published about a year hence.

Referring to Mr. Fuller's discussion of the germicidal treatment of the effluent of coarse grain filters, I would say that for the last six months our department has been working coöperatively with the Bureau of Plant Industry, United States Department of Agriculture, in studying the effect of sterilizing the effluents from both coarse grain filters and from sand filters by the use of copper sulphate and also by the use of chloride of lime. The results of these studies will also be printed in the above-mentioned report.

Mr. Earle B. Phelps. — Mr. Fuller's paper contains such a wealth of valuable information and suggestion that any attempt to discuss it in full is out of the question. There are two subjects, however, which appeal to the writer somewhat more directly than the others, which will here be taken up, namely, sedimentation and sterilization.

The Columbus results undoubtedly embody the best experimental data on sedimentation thus far available. They indicate clearly the proper combination of the two important variables, time and velocity, for the most economical application of sedimentation to American sewages. Much confusion exists in the literature concerning the nature of the so-called colloids in sewage. Physically the colloidal state represents a condition intermediate between solution and suspension. Colloids will not settle out, neither can they be filtered out to any extent by filter paper. In this respect they are identical with dissolved substances. They differ from the latter in their inability to diffuse through animal or other membranes such as parchment, parchment paper or collodion.

In addition to true colloid, there is in sewage a considerable amount of material which is so finely divided that it will never settle owing to the resistance of the liquid. This resistance is not strictly a simple function of the downward velocity, for if it were all particles heavier than the liquid would settle, but is the sum of a velocity function plus a fixed resistance. Hence if the pull of gravity is less than the fixed resistance no motion results. It is strictly analogous to "starting friction." Since the resistance is a function of the viscosity of the liquid, it is natural that in sewage there should be found a considerable amount of material which will not settle but is nevertheless not colloidal. This point has been particularly studied to determine the relative amounts of this non-settling suspended matter in raw and septic sewages. After the regular determination of the suspended solids a chloroformed sample was allowed to settle for 4 days and the suspended solids again determined in the supernatant. The average results of this study, covering a period of 15 weeks, and involving the analysis of 15 samples of each kind, are here given.

TABLE OF SUSPENDED SOLIDS BEFORE AND AFTER FOUR-DAY SEDIMENTATION PERIOD.

AVERAGES. PARTS PER MILLION.

	Initial.		Final.	
	Total.	Loss on Ignition.	Total.	Loss on Ignition.
Raw sewage	134	40	41	30
Septic sewage,	72	16	22	20

It appears, therefore, that there are in raw Boston sewage about 41 parts of suspended solids (non-colloidal), which will not settle out in 4 days, and that the action of the septic tank reduces this amount by 50 per cent.

In regard to chemical sterilization, the writer is in full accord with Mr. Fuller in his views on the importance of this method of treatment. Of all the various disinfectants which have been proposed, compounds of copper and of chlorine alone bear promise of practicability, and it is believed that the latter will ultimately be found to be the more suitable. Even if it should develop that the cost-efficiency of these two classes of disinfectants is at present about equal, the fact that copper is a commodity of limited supply and ever-increasing demand, making it probable that the cost of copper treatment will increase year by year, while chlorine is unlimited in supply and ever decreasing in cost with improved methods of manufacture, strongly favors the latter.

Mr. Fuller expresses the view that certain estimates made by this writer on the cost of manufacturing chlorine electrolytically are far below what would be the actual cost in most places. Two separate points are here involved; first, the cost of electric power; and second, the cost of manufacturing chlorine from salt by the use of electricity.

Electric power was figured at 0.6 cents per kw-hr., this figure being based upon the use of run-of-the-mine bituminous coal at $2.00 per ton. English estimates, by Digby and Shenton, referred to by Mr. Fuller, are 2 cents per kw-hr. At Salem, Mass., electric power is purchased after pumping sewage at 1.25 cents per kw-hr. Data on the actual cost of production are not readily obtainable. That the writer's estimates are not far from actual figures may be seen by a comparison of the cost of pumping water, a process at least no more economical than the production of electric current. At the Chestnut Hill high-service pumping station of the Metropolitan Water Works the actual cost for the year was 0.58 cents per h. p. hour, or 0.78 cents per kw-hr., coal costing $3.91 per ton. At $2.00 per ton the cost would have been 0.59 cents per kw-hr.

The estimate of 0.6 cents per kw-hr., exclusive of fixed charges, is, therefore, not unreasonably low, although admittedly it is based upon the results obtainable only with a plant of considerable size (300 kw.) and with cheap fuel. In the final calculation an additional sum of 0.3 cents was allowed to provide for a $50 000 power plant, which, it is believed, will also allow for some increase in the cost of fuel.

As to the cost of manufacturing chlorine electrolytically, our point must be made perfectly clear. The writer's proposal to use electrolytic chlorine, or bleaching powder prepared from chlorine, is entirely distinct from the various English processes and the older American Woolf process. These latter make hypochlorites, or oxychlorides as they are often called, in one operation, the actual result being obtained at great sacrifice in efficiency. On the other hand, free gaseous chlorine can be made at much greater efficiency per pound of available chlorine, and the writer is convinced can also be used more efficiently. From this chlorine bleaching powder can be prepared if so desired. English bleach is sold in the American market in competition with the home-product at a price which makes the available chlorine cost 2.5 cents per pound, or less than one third the estimated cost of chlorine in the so-called oxychloride form. This serves to indicate the relative efficiency of the two processes.

The use of free chlorine, prepared at the disposal works, would effect a saving of at least the cost of lime and the extra cost of preparing, marketing and shipping bleaching powder. Since the latter can be bought at 2.5 cents per pound of available chlorine, it seems a very conservative claim that electrolytic chlorine can be prepared for 2 cents. On this basis the cost of chlorine for sterilizing effluents with 5 parts per million would be 83 cents per million gallons. These statements apply only to those works whose requirements would warrant the installation of the necessary chlorine and power plant, or where cheap power is already available. For smaller towns, also, where municipal electric lighting and power stations are already installed, the manufacture of chlorine could be undertaken at reasonable cost. Elsewhere the purchase of bleaching powder would be found most advantageous. At current Boston prices the use of bleach would increase the cost of chemicals to $1.05 per million gallons of effluent.

Thus far nothing has been said about the valuable by-products of the electrolytic process, caustic soda, which is not obtained in the English processes. This would be produced in an amount practically equal to the amount of chlorine manufactured. Being used extensively in the soap industry, it would always find a ready local market, and its value would to a large extent offset the cost of the process. If it could be used without concentration, just as it leaves the chlorine plant, a great economy could be effected. Such a result could be brought about by the establishment of a soap works in the near vicinity. Under such conditions the value of the caustic soda would almost pay the cost of manufacture of the chlorine.

It will be of interest to compare the cost of supplementary sand filtration at Baltimore, as estimated by the Board of Advisory Engineers, with a liberal estimate of the cost of sterilizing the same effluents. To avoid debatable ground, it will be assumed that bleaching powder will be used at the market price. The sedimentation basins provided for in the plans for trickling filters make it unnecessary to add any special treatment works except a suitable mixing chamber and tanks for the preparation of the bleaching powder solutions. The entire plant could be run by three extra laborers in connection with the main works. A small amount of power would be necessary for the mixing devices. The estimate for sand filters does not include the cost of the 100 acres of land necessary, while the estimate for sterilization can undoubtedly be reduced by the manufacture of chlorine on the premises.

Table.

Comparison of the estimated costs of treating 75 000 000 gal. per day of trickling filter effluent at Baltimore by (*A*) supplementary sand filtration and (B) sterilization with bleaching powder, applying 5 parts per million of available chlorine.:

	A	*B*
Construction	$1 040 750	$25 000
3 per cent. interest	$31 221	$750
10 per cent. depreciation	......	2 500
Annual operation	55 000	35 000
Total cost per annum	$86 221	$38 250
Cost per million gallons	$3 15	$1 40

Mr. John W. Alvord. — The paper of Mr. Geo. W. Fuller, embodying as it does not only a review of the work done at the Columbus Testing Station but also the matured opinion of the author upon the results secured, is of particular interest and value.

That portion of the paper dealing with the septic or sedimentation tank acquires a new interest from the recent decision in the New York courts in the Saratoga Springs case on the validity of certain patents connected with the septic tank. Undoubtedly that opinion will be appealed from, but in the meantime a very comprehensive opinion of the court in the matter would seem to foreshadow a favorable result from the point of view of the general public.

The writer, having been connected with the original investigation at Columbus in 1898, referred to in Mr. Fuller's paper, has taken especial interest in the solution of the problem in that city. It may not be uninteresting to review briefly the condition of the art at the time this first report was undertaken. Sewage disposal science was at that time in progress of rapid evolution, or one might almost say, revolution, — a revolution, indeed, quite foreseen by those favored few who had been working along bacteriological lines, but which by the general public, and even by the greater portion of the sanitary engineering profession, was not fully understood.

Sewage purification in America was limited to an understanding of intermittent filtration as developed and practiced in Massachusetts; also to that type of minor septic plants so happily worked out by Colonel Waring for the disposal of house

wastes, and chemical precipitation which had been developed in England, and, in connection with land disposal as a final stage, was generally supposed to represent the best attainable practice of the day for the larger class of problems. In certain favored localities we had broad irrigation, and sewage farms had their advocates. Some combinations of all of these forms of sewage treatment, together with minor use of tankage, were about all the available methods open to conservative consideration for the solution of the problem at Columbus, with its flow of something like 10 000 000 gal. of sewage per day.

Under such circumstances the study was undertaken with a full realization of the difficulty and magnitude of the problem. A prior inspection of European sewage purification plants had brought familiarity with the difficulties encountered abroad, and the undertaking was seen to be an intricate problem at the best. At this time, too, there was not a full understanding of the difficulty of applying intermittent filtration, as successfully practiced in Massachusetts, to the different topographical and soil conditions of the central West.

Intermittent filtration, broad irrigation and chemical precipitation were studied. Sedimentation and tankage were at first not thought applicable on so large a scale. During the investigation there was published in England Professor Dibden's book on the experiments with coke contact beds at London; this was an illuminating help, but at the same time a somewhat embarrassing one, as it unsettled the question of the available methods.

About the same time there was published in the *Engineering News*, for the first time in this country, a description of the septic tank at Exeter, which seemed to show that tankage was applicable to the larger problems. The similarity of the Exeter septic tank to the domestic installations of Waring in this country did not escape attention, but it was felt that to enlarge this application of tankage to the dimensions required by the Columbus problem would involve radical recommendations in new and untried fields. On the other hand, the experiments of Professor Dibden with coke breeze filter seemed to follow logically in many ways those experiments of the Massachusetts State Board of Health upon coarse grain filters which had been previously made.

Percolating filters at this time were, of course, quite unthought of. More embarrassing conditions could hardly now be conceived than those which confronted an engineer studying a

large proposition at this transitional period. On the one hand, if he escape the evils of undue conservatism by adopting in some form the newer methods, he might escape the imputation of being behind the times, but, on the other hand, he might easily fall into the difficulty of having recommended that which later on might be found to be absurd.

The establishment of an experimental station was thought to be impracticable under the laws then in force. The only arrangement which seemed to be possible under the circumstances was to suggest a conclusion which should be definite, and then proceed in such a cautious and experimental way that the result would be ascertained in advance of the main expenditure. Thus arose the peculiar conditions which resulted in outlining the entire plant, with the provision that a small portion of it should first be constructed and carefully studied. With these precautions it was deemed not too rash to recommend coke breeze filters or contact beds, as they would now be called.

The septic tank, as glowingly described, with its new and unfamiliar title, was passed over with such favorable comment as might insure a possibility of change of opinions either way. The report at the time it was published was criticised as extremely rash, and so much was said about the improbable schemes from England that found willing believers that no one could be humanly blamed for later enjoying the complete conversion of the critics, one after another. It was the first report that had been made in this country on the newer biological processes for any considerable problem, and seems unduly conservative in the light of later developments. In looking it over the writer is amused at the agility with which he climbed up on the fence over some questions and remained there to watch events; but better men have found themselves in the same predicament. Perhaps the greatest mistake of the report was that it did not stand out more strongly for adequate experimental work in the face of the legal and financial restrictions which then surrounded the city's action.

The rapid introduction of tanks for preliminary treatment of sewage in the central West gave that section of the country perhaps earlier knowledge as to the characteristics which should govern and control their management. The writer's first septic tank, as such, was constructed in 1898, and in the first season's observation of its working he formed some of the ideas which have since been fully developed elsewhere and largely approved.

These relate specifically to the fact that sewage varies greatly from time to time in character, in strength and in temperature; that these variations retard or accelerate the septic action, and that, therefore, tanks should be provided with compartments by which means the flow could be controlled so as to be adjusted to the character of the sewage which was to be treated.

The approval which Mr. Fuller has shown in his paper of this idea is peculiarly gratifying, because it is the one small feature which the writer has fondly hoped would be his contribution to the art. The control idea, not long since emphasized by Stoddart, of England, in his paper on the "Tankage of Sewage," has not ceased to have its value, though it may be admitted it is not necessarily so delicate an adjustment as was first thought.

The multiplication of sewage plants with preliminary treatment in tank has been very rapid, especially in the West. The writer has lost count of even the important installations that have been put into operation. It is a common experience in traveling to meet with plants of which there has been no published description. A large number of intelligent sanitary engineers are now working in this field, and their work is increasingly valuable.

Most of the Western experience has been gained by close observation of full-sized working plants rather than by laboratory experience or analysis, and it has not been our good fortune until recently to obtain from any source funds sufficient for careful and extended bacteriological and chemical investigation even of full-sized working plants, but this difficulty has been offset to some extent by the opportunities afforded to see so many plants working under varied conditions. The deductions drawn from these conclusions, while not always capable of being stated in the exact language of the analyst, are nevertheless most valuable information to those who have the opportunity to acquire them. It is, therefore, gratifying that practice based on such observation has been reduced to exact statement by the careful and accurate methods of the Columbus tests.

The writer agrees fully with what Mr. Fuller has said about the desirability of septic tanks being so operated as to not produce a greatly decomposed effluent. The liquids of sewage are usually susceptible to immediate filtration. It is the solids which it is desirable to detain and to break down by septic action; therefore the details of the tank should be so arranged that they accomplish the full retention of the solids, including,

where possible, all the lightest suspended matter, and yet facilitate the rapid passage of the liquid through the tank. This principle did not occur to the writer in connection with his earlier tanks, but of late has occasioned him much thought, and it is believed that there is room for important future development along this line. Suggestions made by Stoddart in England are for the separation of the inflow into two parts, the one containing the least suspended solids to be passed rapidly to the final compartment of the tank near its outlet, while that portion containing most of the suspended solids passes to a more prolonged rest.

The writer's attempts at a solution of the difficulty have come about in the design of a so-called circular decantation tank, a description of which may be of interest here. This is best shown in the design for a sewage purification plant for Bloomington, Ind. (10 000 population). The incoming sewage flow is admitted upward in the center of the tank; suitable circular baffles and walls impeded its progress radially outward so as to retain the heavier solids in the central compartment as much as possible. As many concentric baffles and walls may be introduced as seem desirable. The outflow from the tank and through the circular baffles is made practically uniform throughout their entire circumference. In this way slow radial outflow is everywhere developed in the tank, yet leaving the passage of the liquid from inlet to outlet with a comparatively short path. Means for regulating the diffusion of the sewage from the central inlet may be introduced in the circumferential outlets. The compartment system can be retained so that the effective capacity may be adjusted to the flow in the same manner as in the rectangular form of tank. This form, as a minor consideration, lends itself to economical construction, and the central compartment is capable of being flushed out through the inlet by suitable valves without emptying the remainder of the tank.

The further purification of the sewage may be effected by a radial dosing chamber or contact bed as part of the circular form, thus reducing the length of carrier or distribution pipe to a point compatible with reasonable elasticity of control. Great compactness is thus secured for the entire arrangement, and a minimum of land will be found necessary for the purpose.

The writer has been impressed for some years with the desirability of discovering means for retaining the finer suspended matter within the tank and preventing the unnecessary

enlargement of filters due to clogging. It is suggested that with the circular form of septic tank, here illustrated, this might be accomplished in larger plants where attendance was necessary by some form of strainer, either of hay or excelsior, which could be inserted in the numerous small outlets or overflows in the outer rim of the tank, the filtering medium being renewed from time to time as necessary. The amount of such strainer material might not be unreasonable, and ought to effect considerable mechanical clarification.

Another suggestion for this problem lies in utilizing roughing filters between the septic tank and the final filtration. This is, of course, only practicable where the first cost and operating expense of such filter is considerably less than the excess area of final filtration necessary. Such roughing filters might proceed along the line of those employed in Philadelphia in water filtration, or they may be built in the form of combined contact bed and dosing chamber; practically they are rapid rate contact beds, with contact material coarser than is usually used. Suppose that some form of honeycomb structure could be adopted in these roughing filters so that the voids, instead of being 30 to 40 per cent., as will be the case of stone or other material of like nature, could be raised to 60 or 70 per cent., as would be the case were they filled with farm tile or with hollow building tile, or even with brick laid up loosely. This idea has been suggested by Professor Dibden, and he calls such filters multiple surface filters, because the contact surfaces are retained to a large extent, while the voids are largely increased. It should be expected that such filters as these might be preferably worked at a very high rate and remain without clogging for a long time; perhaps seven to ten million gal. per acre per day would be practicable. Where trickling filters or intermittent sand filters are to follow the septic tank the substitution of an intermediate stage allows the combination of a rough contact filter and the dosing tank to good advantage. Thus in the Bloomington, Ind., plant shown this combination is effected. Rates for this so-called honeycomb contact dosing chamber are placed at 7 000 000 gal. per acre per day; and should it not prove as practicable as is hoped, the filtering material may be used elsewhere and the chamber used either as a dosing chamber or added to the septic tank capacity.

This is one of the experimental methods necessary for progress in actual practice which, however, does not involve appreciable waste of funds. It would be interesting if some of

our eastern experiment stations would undertake to demonstrate these ideas and give us some accurate statement of what is possible along this line.

The percolating filter is now the favorite design for the central West, where some dilution can be obtained for the effluent. Where high degree of purity is demanded, intermittent sand filters at such comparatively high rates as 0.2 to 0.4 million gal. per acre per day are considered essential and furnish an effluent of high class.

Even where sand is abundantly found in place the percolating filter is often the more economic installation. Preliminary studies for the sewage plant for the United States Steel Company's new city at Gary, Ind., have shown this to a remarkable degree. This enterprise, situated at the southerly end of Lake Michigan, is developing a mill site covering 1.5 sq. miles on the lake shore, and a town site of 2 sq. miles completely developed, with all city improvements. The water supply is derived from Lake Michigan, and of necessity the sewage will all ultimately have to be purified before emptying it into the Calumet River. The soil underlying and surrounding this new city consists of lake shore sand to a depth of nearly forty feet, yet preliminary studies have shown that percolating filters built of broken stone, brought from a considerable distance, will compare favorably in cost with intermittent sand filtration as a final stage. The deciding factor here is largely the cost of the land, which has rapidly increased in value in that vicinity. But even with cheap land, this sand in place does not indicate marked advantage for intermittent filtration treatment unless the highest purity of effluent is necessary.

It is interesting to call attention to the revolution in ideas which has come about through some of the newer biological processes. We formerly used to hear much about sewers of deposit, and it was thought egregiously bad practice to construct large sewers with stagnant or sluggish flow, as they would then become a menace to the health of the community by breeding disease in their midst. This thought seems to be passing away.

In constructing the main sewer for the new city of Gary there has been the necessity of building for a large future area not now settled. It has been suggested that the actual construction of the sewage purification plant for this district may be postponed to some extent by utilizing a portion of this main sewer as a septic tank for the earlier years, there being con-

siderable dilution available both from ground water and at the outlet in Calumet River. Accordingly plans have been prepared for damming the outlet of this sewer to a sufficient height to slow down the flow to a point which will be desirable for septic purposes, or a retention which will correspond to 6 or 8 hr. rest. It is thought that this will afford relief for some time to come. It is evident that, if successful, this suggests a new use for large unemployed outlet sewers, and is further suggestive as to possibilities of permanent application.

Mr. Fuller's paper draws out the interesting fact that the problem of sewage purification is increasingly easier with the more diluted sewages. It has been noted by the writer repeatedly that a system of separate sewers intended to receive only the household waste, but which, through inadvertence or ignorance has been allowed to receive some portion of the rainfall, has unexpectedly resulted in favorable operation of the sewage purification plant. Indeed, the introduction of a considerable and not unreasonable amount of pure water to a septic tank often facilitates its work. Evidently the reason for this is that the toxic effects of over-septicized liquid are removed for the time being, and if the added water is not so great in amount that suspended matter is washed into the effluent, the process is beneficial. The addition of considerable ground water into the separate systems of sewerage is not always to be dreaded, and the resulting necessity of caring for it in the sewage purification plant is often the occasion of much needless solicitude. It is a matter of common knowledge that the most difficult problems which confront the sanitary engineer are those in which no dilution water enters the sewers, and the resulting concentrated sewage is, as a consequence, found to be exceedingly difficult to purify.

In general, the sewage of the larger towns and cities, with its more even flow and uniform character, presents the least difficulties in purification, while the most difficult problems in domestic sewage are the small institutions with scant water supply and no available dilution for effluents.

Mr. A. Elliott Kimberly. — As possibly of some interest in connection with Mr. Fuller's admirable review of the Columbus sewage data, the writer desires to present a few views regarding the advantage of flexibility in the design and operation of septic tanks.

While the subsidence of sewage in septic tanks exerts the well-known equalizing effect upon the character of the incoming

sewage, yet, of course, at times of wet weather and during drought, wide variation is remarked in the composition of the resulting effluent. Depending upon the quantity and the character of the raw sewage, the actual period of subsidence required for maximum suspended matter removal varies widely, and under these conditions a septic tank arranged with several compartments affords many advantages from the operating standpoint.

During high flows the flexible plant allows the operator to employ a greater tank capacity, thereby overcoming in part the effect of the increased flow by permitting the linear velocity to be maintained more closely to the normal for the given sewage. Without the option of increasing the tank capacity during such periods under the increased velocity the suspended matters may be imperfectly removed, and sludge deposited under ordinary flow conditions may be scoured out, both features tending to clog the oxidizing devices to which the sewage is then applied.

Another feature obtaining in a non-elastic layout during high flows is that while the total feet of travel may cause a normal removal of suspended matters, yet the zone of heaviest deposition is thus transferred to a point nearer the outlet, and as soon as decomposition begins in the sludge deposit the rising and falling sludge may in part be carried out with the effluent since less opportunity is afforded for the subsidence of the suspended matters that are introduced into the sewage as it passes over the point of maximum sludge deposition and decomposition. Extending the views of Mr. Fuller with reference to a thorough screening of the sewage before septic treatment, the writer believes it to be important to restrict the deposition of the coarse suspended matters to the inlet half of the tank so that the comparatively greater fermentative action of the coarse matters may not detract from the efficiency of the tank by virtue of their deposition too near the outlet to admit of their retention until so reduced by bacterial action that they form a part of the thoroughly hydrolized deposit of sludge. The well-known "blow-up" periods in septic tanks of course cause large quantities of suspended matters to escape from the tanks, to the great detriment of the filters, and some efforts have been made to overcome this damaging feature by the use of screens, scrubbers or strainers, but so far as the writer is aware none of these straining devices has been entirely successful in practice. A septic tank on the compartment plan, however, especially one

in which there may be obtained a tandem effect, would appear to be going far toward the prevention of clogging in filters in cases where subsidence forms a part of the preparatory treatment to which the applied sewage is subjected.

Mr. F. A. Barbour. — The present contribution of Mr. Fuller is a most welcome addition to the literature of sewage disposal, not only as a summary of the valuable series of experiments made at Columbus, Ohio, but as an unusually frank and confidential statement of the author's personal interpretation of these experiments in the light of present-day information. Carried out on a large scale, the work at Columbus has unquestionably placed high-rate methods on a better foundation than ever before in this country.

The history of sewage purification, starting with the adoption of the water carriage system, runs through the periods of irrigation and chemical precipitation in English practice to the time of the Massachusetts experiments, by which the underlying chemical and bacterial agencies were first clearly outlined, and intermittent sand filtration made for New England the recognized method of disposal. English engineers not having sand but appreciating the bacterial and chemical reactions proved by the Massachusetts work to be essential to success, proceeded to utilize this knowledge in the development of various high-rate processes, such as contact beds and sprinkling filters. Numerous plants of these types were constructed, and it is to England that, during the past ten years, we must look for the greatest progress in sewage disposal work. Some high-rate plants, largely based on English results, have been built in this country, but a series of experiments such as those at Columbus was most desirable for a better understanding of the processes involved and as a demonstration of the adaptability of such methods to the temperature conditions of this country.

The direct practical outcome of the Columbus work has been the adoption of the septic process and sprinkling filters — in some cases followed by sand filtration — at a number of the largest disposal plants yet undertaken in this country. The feeling of the writer is that a long step forward has been taken in this present appreciation of these more intensified processes but that some conservatism may not be amiss in the adoption of rates of operation and perhaps in the use of such methods, except where high-class supervision is assured. In saying this the value of good design and the possibility of discounting many troubles in operation thereby are thoroughly appreciated,

but it is believed that the more highly developed the process the more intelligent must be the supervision of the plant. In the case of very large works where the magnitude of the undertaking will of itself insure good maintenance, it will be possible to operate all parts of the plant at high efficiency, but in small works the exigencies of average municipal managements must be given consideration. Personally the writer feels strongly on this question of disposal works maintenance. A plant entirely successful under one management will, with a change of authority, by politics or otherwise, rapidly go to the bad through neglect, and the most simple and that which will stand the greatest abuse has much to recommend it. Perhaps the more obvious requirement of careful management in the case of high-rate plants will insure a better standard of maintenance than has been generally given to the disposal works already constructed in this country and so justify the use of such methods even in the smaller installations. In the light of experience, however, the writer is inclined to discount the possibility of maintaining small sprinkling filters at the same efficiency and operating rate as may be reasonably adopted in large installations.

The time has, however, unquestionably arrived when the use of these higher-rate processes must be given consideration in the working out of any problem, whether it be in Massachusetts or the Middle West. Where sand is economically obtainable, intermittent filtration is probably the safest method for the average community; but lifting of the sewage to considerable heights through long force mains in order to reach such material can be justified only after a careful examination and rejection, for cause other than conservatism, of these other methods.

The recognition of the septic process as a valuable preparatory treatment by the Columbus work is a source of satisfaction to the writer. Since 1900, in all plants constructed by him outside of the state of Massachusetts, this has been a part of the scheme of disposal, and in all cases with results which have justified its use. Thus far fortune has favored these plants apparently in furnishing the necessary bacteria without special seeding, but why some work better than others cannot be determined from the period of septic exposure or the chemical characteristics of the sewage. As Mr. Fuller states, there is much to be done by bacteriologists and it is to be hoped that in some of these larger plants to be constructed it may be possible to work out the causes not now understood of relative success or failure in septic work.

The writer agrees that septic treatment does not enable higher rates of filtration to be maintained other than as the amount of suspended matter is reduced in the sewage by its use. Its value lies in the economy or necessity of removing as much of the solids before filtration as may be physically possible and in the subsequent liquefaction of a portion of the intercepted solids, thus reducing the amount of sludge to be handled. In the experience of the writer the deposit, which may from time to time require removal from septic tanks, is less obnoxious than the ordinary sludge from settling tanks emptied at intervals of a few weeks. The validity of this statement depends entirely on the premise that the tanks are working properly. It is not necessary that the septic process should liquefy all the solid matters retained in order to justify its use. As to how much screening is advisable, this depends on the collecting system of sewers. With a separate system and no abnormal manufacturing conditions, if the inlet of the septic tanks is so designed as to distribute the solids over the surface area of the tanks, it is believed that only coarse screening is necessary.

Despite the present popularity of sprinkling filters, contact beds will probably continue to hold a place in disposal practice. This method has the advantages of requiring less height for its installation, of being better adapted to low temperature conditions and of being more sightly and less liable to the creation of odors during the application of sewage than sprinkling filters. It is well adapted for institutional and small municipal work where sand filters cannot be economically used. In such work, where plants must be located comparatively near dwellings, a contact bed filled from below has particular advantages in absence from odors and in the fact that it may be operated without the sewage appearing in sight at any stage of the process.

Such application of sewage suggests a query as to the relative value of the anaerobic and aerobic periods in contact work. While sprinkling filters are an oxidizing process throughout, contact beds alternate between anaerobic and aerobic conditions. When filled from above, the sewage, if well distributed, trickles over the particles of the bed and for the time being partakes of the action of the regular sprinkling filter. While without proof by actual comparative analyses, the writer has believed that the distribution of the septic effluent over the bed surface and this trickling action during the filling of the bed have been of some value in the contact beds at Mansfield, Ohio.

In sprinkling filter work the method of applying the sewage

is the factor most essential to success. The writer believes that with present knowledge it is advisable to so arrange the dosing apparatus that the liquid may be applied continuously under a constant head, or intermittently through a dosing tank, discharging at short intervals, with a variation in head on the nozzle such that the spraying radius will be changed so as to practically cover the entire area of the bed. This is the arrangement proposed for West Chester, Pa., in plans submitted last year, which involve the use of septic tanks, sprinkling filters and finally sand filtration.

One of the most interesting features of the Columbus work is the unequivocal statement that a non-putrescible effluent is sufficient for local conditions, and the statement that while some disease germs may travel the intervening miles to the nearest water supply, the difficulty of purifying the water will not be materially increased. Such a conclusion is based on the premise that no river of any size running through an inhabited territory can be maintained at a drinking standard and that all surface water should be purified before use. This being accepted, no material damage is done to the riparian owners if an effluent of such degree as to not appreciably add to the difficulty of purifying the water is turned out. Personally the writer believes this to be a reasonable position and that by the adoption of such rational standard greater sanitary progress will be effected than through any attempt to reach the impossible ideal of maintaining rivers in anything approaching their original purity. There is, however, always something to be gained by setting a standard high and there is danger in any official or formal acceptance of a certain degree of inevitable pollution. It may be entirely reasonable, but it seems a cold-blooded proposition, to discharge the septic sludge into the Scioto during periods of flood flow. Perhaps the dilution is sufficient to prevent a nuisance and there may be but few disease germs in the decomposed sludge, but it would seem that by its discharge an additional and unnecessary burden is thrown on possible users of the water below. Merely from a politic standpoint provision for the disposal of this sludge in some other manner might have been a good investment.

The rights of riparian owners in such a case are of general interest. At the present time all manner of opinions and standards are being maintained. Recently in New Brunswick the board of health and the provincial government refused to sanction the discharge of the sewage of 6 000 people into a river with 14 000 sq. miles of watershed and no public water supply

within 80 miles of the point of discharge. The river water, without this sewage, is unfit for domestic use, and apparently the entire decision was based on the common-law rights of the riparian owners to receive the water "as it is wont by nature," or as near that condition as it can be maintained by preventing the obvious discharge of sewage through artificial structures. Testimony as to what is being done in other parts of the world had apparently little effect upon the authorities, and the position taken is that now and before contamination has become great is the time to prevent pollution of rivers so far as may be done through reasonable governmental control. Such position is very different from the intention to discharge septic sludge into a river of but a small fraction of the size of that to which reference is made. In any case of stream pollution, as in the case of the contamination of shell fish, a reasonable balancing of the cost of obtaining higher degrees of purity in effluents with the importance of the interests affected should be the governing condition, but what about the legal rights of such interests? It is not always necessary that damage capable of demonstration by analysis or sensuous evidence should be done in order that the damage be material.

Prof. C.-E. A. Winslow. — Mr. Fuller's admirable review of the current art of sewage treatment furnishes new evidence of the remarkable progress in this branch of engineering which has marked the last few years in the United States. Since the original experiments of the Massachusetts State Board of Health, which laid the foundation for the whole science of sewage disposal by biological methods, the most important developments along this line have been made by English engineers; now, once more, American practice promises to occupy in some phases of the subject a position of international leadership.

In regard to the removal of suspended solids, in particular, the Columbus results are unique in completeness and precision, Mr. Fuller's discussion of the septic tank and its working seem also deserving of special comment. This device is rightly treated as simply a sedimentation tank in which part of the deposited sludge is liquefied, the action of the tank upon the liquid itself being harmful rather than beneficial. Emphasis is well placed, too, on the importance of the specific bacteria concerned in the septic process as offering a possible explanation for the marked differences observed in practice between the operation of different septic tanks. The fact that hydrogen sulphide is not formed from the sulphates in the Columbus sewage

is somewhat surprising. In the septic tanks at the Technology experiment station, large amounts of hydrogen sulphide are produced by the septic process. It is very possible, as Mr. Fuller suggests, that the organisms which carry out this decomposition are absent from Columbus sewage. In Boston sewage all conditions seem right for the most efficient septic action. For two successive periods of two years each, septic tanks have been operated at the Technology experiment station without serious sludging. In the first period 0.60 cu. yd. of sludge were deposited in the tanks per million gallons of sewage treated, as against 2.68 cu. yd. at Columbus. Before septic treatment at Boston, 0.65 cu. yd. of detritus per million gallons are taken out by a screen and grit chamber.

The only point at which I should take serious issue with Mr. Fuller is in regard to the bacterial purification effected by biological processes. He says in one place, "The removal of bacteria in sedimentation or septic tanks seems to approximate that of the total suspended matter, as shown from the data obtained from comparatively small sewage settling basins and from numerous water settling basins. Bacterial growths of certain species within a septic tank frequently obscure this general statement, which is intended to apply especially to those bacteria originally present in the sewage, and particularly the pathogenic bacteria."

Again, in speaking of trickling filters, he says that the bacterial removal "at Columbus was about 70 per cent. of those in the applied liquid, and it is estimated to be about 90 per cent. when compared with the bacteria in the original sewage. These results obtained with 5-ft. beds would be much higher with deeper beds. The Lawrence data indicate that there would be a total removal of from 95 to 97 per cent. with 10-ft. filters."

Messrs. Hering, Fuller and Stearns based their Baltimore plans upon a similar supposition that "the removal of bacteria by the septic tanks, sprinkling filters and settling basins is in the neighborhood of 95 per cent. of the number contained in the original sewage."

Certain of these assumptions are not justified by any experimental data with which I am familiar. The total bacterial removal effected at Columbus, comparing trickling effluent with crude sewage, varied from 30 per cent. to 80 per cent., and the view that the removal of sewage bacteria is greater than this is apparently founded on the analysis of four samples only. On the other hand, Houston's elaborate studies in England led him

to the conclusion that "the different kinds of bacteria and their abundance appear to be very much the same in the effluents as in the crude sewage," and he found that in no case was the reduction of B. coli and other sewage forms "so marked as to be very material from the point of view of the epidemiologist." Our own results at the Technology station agree fairly well with those of Houston. For two years we have been treating Boston sewage from the main interceptor of the South Metropolitan District on two outdoor trickling beds, each 25 sq. ft. in area and 8 ft. deep, filled with 2-in. stone. One filter takes crude sewage and the other the effluent from an 8-hr. septic treatment in a tank divided into five successive compartments. The effluent from the filter which receives septic effluent is subsequently settled for 2 hr. in a conical tank of a modified Dortmund pattern. Bacterial analyses have been carried out for a year now and the average results for the last 6 months of 1906 are tabulated below. Each figure represents the average of 37 to 40 analyses.

BACTERIA IN BOSTON SEWAGE AND EFFLUENTS.

Averages for July–December, 1906.

	Total Bacteria per Cu. Cm. Gelatine at 20°.		Presumptive Test for B. Coli. Lactose Bile at 37°. Per Cent. Positive Results in .000001 Cu. Cm.	
	No.	Per Cent. Purif.	Per Cent.	Per Cent. Purif.
Crude sewage,	970 000		35	
Effluent from trickling filter,	300 000	69	29	17
Effluent from septic tank,	780 000	20	47	Increase
Effluent from septic tank and trickling filter,	260 000	73	32	8
Effluent from septic tank, trickling filter and sedimentation tank,	340 000	65	27*	92

* In .00001 cu. cm.

As in the Columbus experiments, the trickling filter alone produced about 70 per cent. removal of total bacteria; the gas-forming organisms, however, which probably represent in a general way the B. coli group, were reduced not more, but less, than the total number. In the septic tank, too, while the total bacteria decreased 20 per cent., the gas formers actually multiplied. Septic treatment followed by trickling filtration reduced the total bacteria by 73 per cent. and the gas-formers by only 32 per cent. Subsequent sedimentation, however, did show a

selective action, increasing the total numbers from 73 per cent. of the sewage value to 65 per cent., but greatly diminishing the gas-formers so as to produce a net purification of 92 per cent. Here there was no doubt a large removal of the bacteria in the effluent, accompanied by a multiplication in which the B. coli group did not take part.

In these experiments it does not appear that the intestinal organisms, of which those which give gas in the lactose-bile medium are certainly fairly representative, decrease more rapidly than the total bacteria, but the reverse. They actually multiplied in the septic tank and held their own better than the average of the bacteria in the trickling filter. Sedimentation did, however, produce a large reduction in these experiments.

One may be inclined to guess that typhoid bacilli would decrease faster than the bile-fermenting organisms in septic tanks and trickling beds, but the guess is too vague to be made the basis for quantitative statements of efficiency or for the construction of sewage disposal plants. It is very questionable whether much reliance should be placed on septic tanks and trickling filters for bacterial purification. Sedimentation alone would probably be relied upon by few. These devices are excellently adapted to the ends for which they were designed, the removal and oxidation of organic matter. Often this is all that can be required of a sewage disposal plant. When bacterial purification is also required, it seems probable that subsequent filtration or sterilization must be combined with them.

Mr. F. Herbert Snow. — Speaking generally, the principles of bacteriological processes of sewage purification are so well understood by experts and proven in a few cases in practice, both in Europe and America, that it is unnecessary in a majority of cases where the problem of sewage disposal other than into a stream or body of water must be taken up by a municipality, to go to the trouble of making tests to determine what kind of works shall be adopted. If this were not true, rapid progress in the discontinuance of the discharge of sewage into the waters of a state should not be hoped for, because of the expense involved in conducting conclusive tests. Fortunately the larger municipalities mentioned by Mr. Fuller and the state of Massachusetts have done this work and given the results to the world at large. The Columbus experiments materially add to the knowledge on the subject from the American standpoint.

However, the real essence of the sewage disposal problem, the application of known principles to practice under varying

conditions, has not become so thoroughly understood that inexperienced engineers can tackle any project which may come along with reasonable assurance of unqualified success. Evidence of this fact is manifest in the numerous failures of sewage disposal plants in small communities. Since those best qualified by experience and actual knowledge often approach the solution of a sewage disposal problem with apprehension, surely others should hesitate to make recommendations. There is no work of public utility demanding more careful and experienced consideration than this very one of sewage treatment. It is peculiarly at this time in the development of the art a specialist's problem. No municipal engineer should attempt to solve the problem without the services of a competent consulting expert.

State supervision and approval of plans may help some towards satisfactory results, and should secure them, but it is not good public policy for the state to do much more than advise and direct. The initiative and the burden of responsibility in choosing and putting in force the means with which to bring about the general policy of a commonwealth respecting stream pollution properly belong to the local authorities. And in this work economy and efficiency demand expert service outside of that which the state should render.

In Pennsylvania the largest city has over 1 000 000 population. There are several hundred small incorporated boroughs scattered all over the state. From the standpoint of public health it is relatively more important that the sewage of these small places should be treated. Many of them are foci of infection of water supply; so marked diminution in water-borne diseases cannot be accomplished unless attention be given to the treatment of the sewage there.

The question of preliminary treatment of sewage or the correct capacity for tanks, sand or other filters, where the total cost of the plant is to be from $25 000 to $50 000, is easily within the grasp of an engineer versed in the subject. There is not enough leeway in expenditures to warrant tests to determine the merits of design. Of infinitely more importance are simplicity of design and the fact as to whether the sewers of the town receive sewage only or sewage and storm water. An expert's advice on what should be done where the sewers are on the combined plan may easily save to the municipality more than his entire fee.

Preparatory treatments are of vital importance to the continued success of a plant, more especially if the sewage be a

manufactural one or conspicuously characterized by the inimical wastes of some one industry. It is not safe to put the stamp of approval on plans unless facts as to the quality of the sewage have been given due consideration. Here again the expert is needed.

At present some disposal works are designed to obviate a nuisance in a stream, and where this is the object the problem is different from the other case where the object is to prevent pathogenic poisoning of a public water supply. Disease germs should be killed, if not in the dwelling, then as soon as possible. Barriers against them should be set up all along the line, and it should not be possible for them to run the gauntlet and live to poison the water we drink and the food we eat. Some day it will not be a question in designing a sewage disposal plant whether it will take out 70 or 90 per cent. of the danger and poison, but whether the germs have been completely killed. To-day it is not practicable from the dollar standpoint to accomplish such a result, but it will be in the future. This thought should not be cast aside, but well may influence the location and general layout of sewage disposal works now.

In considering preliminary treatments each process has its advantages and advocates. For instance, strainers are often proposed. While their operation is expensive, yet good results may be obtained thereby, and if economy is not to be the criterion, then the strainers must be accepted. Here again does the value to the municipality of the consulting engineer come into play. The state should not necessarily condemn a process simply because it is expensive, while the consulting engineer upon whom the responsibility of balancing the design rests would withhold approval of a needlessly expensive apparatus.

Plain sedimentation is an efficient preliminary process, but it is not to be preferred to the septic tank for hygienic reasons alone, if for nothing more. Yet plain sedimentation is bound to play an important part, either alone or in modified form in the future. The expert should be consulted.

The septic tank is the most important preliminary treatment because of its hygienic utility. Its value in small towns is enhanced because the minimum of attention is demanded by it. Another great value is the fact that disease germs perish readily and in greater numbers in the septic tank. Its value as a sludge liquidizer is uncertain and depends to a considerable extent upon design, sewage flow and intelligent operation.

The generally accepted opinion that the successful operation

of a septic tank is assured, once the structure is erected, is far from the truth as proved by experience. Mr. Fuller aptly says, "It is not to any practical degree helpful for subsequent filtration, except in so far as the original sewage is clarified by visible means." In other words, plain sedimentation is as advantageous for subsequent filtration. It is the writer's opinion that septic tank operation may be harmful to subsequent filtration, and he sees no reason to change former oft-repeated statements to the effect that the general application of the septic tank process by the hit-or-miss plan should be discountenanced.

There is much to be explained in accounting for the successful reduction of sludge in some tanks and the comparatively unsuccessful reduction of sludge in other tanks. Here is a field of research for the state authorities who maintain a supervision over the operation of a plant which has received prior state approval of design.

In this connection each new disposal works is a testing station, and in time, aided by the right kind of local coöperation and management, the benefits of supervision by the state of all such plants within its jurisdiction will bring compensating values far-reaching in all directions.

In the management of sewage disposal works there will be demanded in the near future specially trained men, and this field is commended to student engineers.

Mr. Fuller's conviction that "a septic tank should be designed with various compartments so that portions may be used from time to time and other portions temporarily thrown out of use," is most earnestly seconded. For a municipality, no matter how small the plant, it is desirable that at least two compartments be provided in the tank.

Whether or not odors will emanate from a septic tank or the disposal works is largely to be proven on trial. There may or may not be odors. Whether they will be objectionable depends primarily upon proximity of dwellings or a much-traveled highway. It is good practice to isolate the plant. How remote it should be is a local question. Upon this point the state authorities must deliberate. It is right there that a difference of opinion may arise between local and central officials. Whether the state would be a party to the defense in litigation for injury to property by reason of a nuisance created by a sewage disposal plant, the plans of which were approved by and the operation conducted under supervision of the state, is not the question. State approval should mean something. The condition of ap-

proval should vouchsafe to the general public, in the interests of public health, proper location and design, efficient management, operation and maintenance. It is a fact that these things cannot be brought about generally independent of state authority.

Intermittent sand filtration, in some instances, even at a higher cost, is desirable where good efficiency is required. This applies particularly to small plants liable to receive the minimum of attention, where, therefore, sprinkling filters or contact beds would be useless. A sand filter can stand more neglect and abuse than any other and still give fair results. In fact, instead of the Massachusetts intermittent sand filter being a thing of the past, the writer concurs with Mr. Fuller's opinion that it is destined to continue to serve a very useful purpose.

Contact filters invite failure more, however, on account of negligent operation than otherwise. Where this process is peculiarly suitable, there is no reason appearing at present why it should not be sanctioned. Mr. Fuller thinks contact filters may be advantageously installed in those instances where they can be used without pumping and where pumping would be required for sprinkling filters. If this were to be the principal determining factor, we should witness in the future the erection of more contact filters than those of any other kind.

The writer views with apprehension the non-conservative willingness of municipal engineers generally to recommend sprinkling filters for every kind of a sewage purification task. Here is an old principle newly applied with little to look to by way of practice, and with much to be observed and learned therefrom, and yet the method is being rashly recommended. The danger of failure is greatest with the smaller plants. Only where works of this kind are of a magnitude sufficient to insure proper management should they be adopted for the present.

The plan of building a tentative installation, or a small part of the disposal works as designed in its entirety, whereby tests can be made in practical every day-week management and results noted as a basis for modification of details for extensions to complete the entire works, is a commendable one and is being fostered in Pennsylvania.

The germicidal treatment of coarse-grain filter effluents will be required more and more in different parts of America until an impetus shall have been given to research that shall result in developing efficient and economical methods.

The setting up of state standards of purification, except in individual cases, is a mistake. What is impractical of attain-

ment to-day in the degree of purification may be easily within reach and desirable to-morrow. Work should be designed and so constructed, if possible, that advantage may be taken of advancement in knowledge when the time for extension of any plant arrives. Above all, state oversight of management of sewage purification works is demanded in the interests of sanitation and good judgment.

Mr. Clyde Potts. — The writer has read Mr. Fuller's paper with much interest and believes the data presented and the clearness of its presentation are potent factors in the evolution of the art of sewage disposal.

There are several points touched on in the paper which are not related to the data given, but which must be apparent to every engineer who has to deal with sewage disposal. They are:

1. — Is it necessary to seed the tanks with proper bacteria to insure successful septic action?

2. — How much truth is there in the theory of bacterial antagonism?

3. — The feasibility of designing a septic tank so that the decomposed sludge may be separated from the decomposing and thus disposed of without creating a nuisance.

On the first point the writer is inclined to agree with Mr. Fuller that the failure of certain septic tanks does not seem to be satisfactorily accounted for except that they are not inoculated with the proper bacteria.

In regard to the third point of the difficulty of properly designing a septic tank. This is a real one. Septic action in tanks as they are now designed is a continuous operation. It is never completed. When sludge is drawn off it is taken from a process of fermentation that is still active. It is like removing the ashes from a fire that still burns. Some of the sludge is wholly decomposed and some still decomposing. Some of the sludge has been decomposed for months and some is recently decomposed. Do sludge tanks as used in England and recently proposed for this country remedy this?

Not only is the sludge drawn from a tank where the fermentation is still active, but the septic tank effluent is likewise still undergoing changes.

In a septic tank it is supposed that the activities are lessened as the outlet is approached; that all the beneficial results are accomplished during the progression through the tank. If a tank is mechanically perfect this may be so. With increased flow progress through the tank is hastened and with the night

flow it is retarded. The deposit of sludge varies with temperature, and consequently the cross section of the tank varies, and with it the velocity of flow. Even in a separate system the sewage flow varies also with rainfall owing to the infiltration. To be mechanically perfect a septic tank should accommodate itself to these variable factors. It is needless to say few tanks do and hence the difficulty.

Another point Mr. Fuller makes is illustrated in Table 5 of the paper, where the comparative costs of different methods of treatment for the Calumet area south of Chicago are given as follows:

Sand filters	\$28 383 000
Contact filters	22 807 500
Sprinkling filters	17 637 500

This is cited as an argument for sprinkling filters being preferable to sand filters. The writer is by no means certain that the different methods of disposal above outlined are comparable, inasmuch as the character of the effluents is not comparable. For the conditions at Chicago undoubtedly either of these methods would give a proper effluent, and for Chicago they would be comparable, but where the effluent is to be turned into potable water, or into waters inhabited by shellfish, would not the quality of the effluent have a commercial value not considered in Table 5? To make the data comparable for a general statement, the quality of the effluent should be considered and the cost expressed in terms of its character. In fact, where the highest practicable degree of purification is demanded, the economies involved would then be reduced to the question, How many acres of sand filters would sprinkling filters as a preliminary treatment save? In such a case sprinkling filters would only be considered as a preparatory treatment.

There is no doubt sprinkling filters possess great advantages over other types, especially contact beds, and mark an advance in sewage disposal, but whether they solve all the difficulties of filtration can be better determined after the Columbus filters are put in actual operation. In the development of the sprinkling filter, the work at Columbus will long stand as a classic. One is impressed with the fine technical character of the work done, and most of all with the vast amount accomplished with so small an outlay of money.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by November 1, 1907, for publication in a subsequent number of the JOURNAL.]

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIX. SEPTEMBER, 1907. No. 3.

MODERN POWER STATION AND ELECTRICAL CONSTRUCTION.

BY W. A. HALLER.

[Read before Louisiana Engineering Society at its meeting, May 13, 1907.]

IN designing a power station and distributing system the first matter to be taken into consideration is the character of service, whether for street railway, lighting, power or for other uses. At the present stage of development nearly every city and town is using electrical energy to a greater or less extent; therefore the designer of a new installation may obtain some kind of data which will be found useful in calculating the present or future requirements as to capacity or kind of service. In the absence of any such data, however, reasonably close estimates may be made on a per-capita basis, although this ratio varies in different localities, the variation being particularly pronounced between northern and southern cities.

Heretofore the most difficult problem before the engineer has been the selection of a type of electrical apparatus which would come nearest to supplying all classes of service, the principal of which have been:

1. 550-volt direct current for railway use.

2. 2300-volt alternating current for lighting use.

3. One of the three or four methods of supplying arc service.

4. Commercial power service; 110–220 or 500 volts direct current or alternating current.

5. Three-wire direct current Edison service for light and power.

In the past, three or four and sometimes all of the different kinds of current have had to be generated in the same station,

each requiring a different form of generator or apparatus, which has rendered the station design difficult and the proper relaying of apparatus almost impossible.

The above remarks, of course, apply to stations supplying all the different classes of service required in any community, as under the conditions formerly existing in this city.

The present stage of development of electrical apparatus enables the designer to install one type of prime mover, or, at the most, two types for all classes of service. The most modern and commonly used is the steam turbine, and this paper will bear largely on the construction features pertaining to the in-

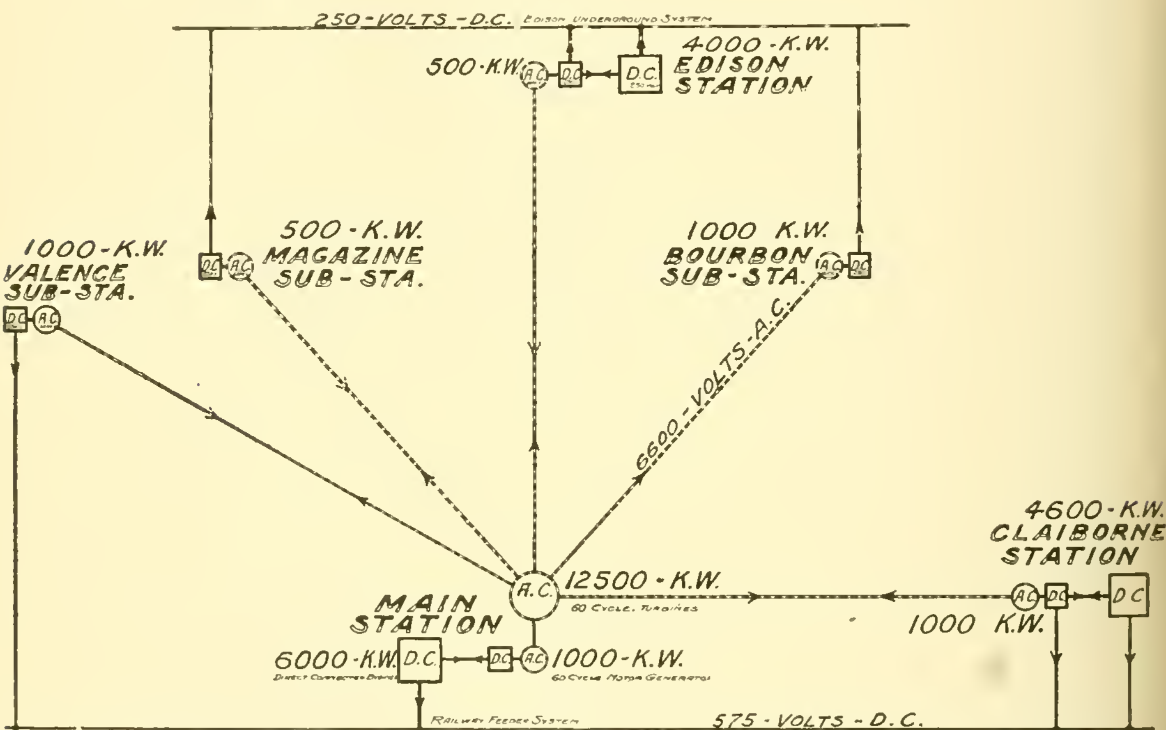


FIG. I. ELECTRICAL CONNECTIONS OF STEAM STATIONS AND GENERATING SUB-STATION.

stallation of turbo generators and their supplementary apparatus. Note, however, that while the steam turbine, is the cheapest and most compact generator produced up to the present time, there are certain conditions under which reciprocating steam engines are still more economical. This would and does apply to the Claiborne power house installation in New Orleans, at which station reciprocating steam engines have recently been installed for the purpose of generating direct current for railway purposes.

The features influencing this were, first, that a considerable amount of 550-volt direct railway current is required at that location; second, condensing water of ample quantity is available;

third, the necessity for transmission lines and motor generators is obviated, except to a limited extent, thus keeping down interest and depreciation charges; fourth, less liability of interruption to service on account of fires or interruptions of service at central station; fifth, generating cost to deliver direct current to railway switchboard, taking interest and depreciation into consideration, is lower.

The New Orleans system, of which this paper is descriptive, consists of one central power generating station, four auxiliary steam stations (two of which will shortly be abandoned), three motor generator sub-stations, with others under contemplation. These are indicated on accompanying diagram, Fig. 1, showing electrical connections by which all of these stations, performing all classes of service, may be operated in parallel and by means of which any piece of apparatus in any of these stations may be made to perform any type of service required, through the medium of transformers and transmission lines, and still further all the stations may be tied together electrically and the loads thereon equalized.

Central Power Station.

The first station to be considered will be the central power station, located at Market and South Peters streets. The capacity of this station is given in the following table:

	Present Installation.	Ultimate Installation.
Electrical generators	17 800 kw.	50 000 kw.
Boilers	10 800 h.p.	30 000 h.p.
Coal bunker capacity	2 000 tons.	5 000 tons.
Equivalent capacity in 16 c.p. lamps	356 000	1 000 000
Approximate coal consumption per day,	200 tons.	500 tons.
Approximate condensing water required per day of 24 hr.	70 000 000 gal.	200 000 000 gal.

The engineering and construction features were conducted as follows: Designs, drawings and specifications were prepared in the New York office of Messrs. Sanderson & Porter, the engineers and constructors. The construction of the turbine station was carried on by a local superintendent, assisted as follows:

Mechanical engineers.

Electrical engineers.

Bookkeepers.

Paymasters.

Foremen, etc.

The actual construction of the station in question was commenced about August 1, 1904. The first new boilers went into commission about fifteen months after the commencement of construction work and the first turbine went into operation two years after commencement, and at this writing the initial construction is substantially complete.

The construction costs and records were kept as shown on the following form, each feature of construction being assigned a number, sub-classifications being used under each number. Labor costs and material costs were kept separately.

	Material.	Labor.	Total.
No. 1. Engineering,	....	....	....
No. 2. Pile driving,	....	....	....
No. 3. Earth, excavating and removal,	....	....	....
No. 4. Foundations,	....	....	....
No. 5. Intakes,	....	....	....
No. 6. Building,	....	....	....
No. 7. Boilers,	....	....	....
No. 8. Economizers,	....	....	....
No. 9. Stokers,	....	....	....
No. 10. Coal-handling machinery,	....	....	....
No. 11. Ash-handling machinery,	....	....	....
No. 12. Stacks,	....	....	....
No. 13. Piping,	....	....	....
No. 14. Pumps,	....	....	....
No. 15. Condensers,	....	....	....
No. 16. Turbines,	....	....	....
No. 17. Engines,	....	....	....
No. 18. Switchboard,	....	....	....
No. 19. Station wiring,	....	....	....
No. 20. Machine tools,	....	....	....
No. 21. Temporary job lighting,	....	....	....
No. 22. Liability insurance,	....	....	....
No. 23. Contractors' equipment and tool account,	....	....	....
No. 24. Temporary operating expenses chargeable to construction,	....	....	....

In addition to the above, several other miscellaneous classifications are used, dependent somewhat on the work in hand.

Pile Driving. — The central power station is supported entirely on piling, most of which was about 50 ft. in length, some of the piling being set to a depth of 30 ft. below surface, making a total penetration of 80 ft. Nearly all of the piling was placed approximately 3 ft. centers, making something like 4 000 round piles for the job.

The deep trenches and all other foundation limits were bounded by 6-in. grooved piling 30 to 50 ft. in length, 2 by 4 in. splines being used to insure alignment and tight joints. To successfully excavate to any great depth in New Orleans, the excavation must be protected by absolutely tight sheet piling and the bracing must be capable of resisting any pressures exerted on the sheeting by the surrounding earth. In the work, calculations were invariably based on the surrounding earth being of a liquid form and of approximately twice the density of water, or about 120 lb. per cubic foot.

Excavating and Earth Removal. — The total excavation amounted to about 8 500 yd., some of which was done by means of an orange peel digger, and the earth was removed by means of a tramway. Owing to the comparatively small volume of excavation, however, and the numerous obstructions, no very unusual success attended this feature other than that the progress of the work was much faster than could have been expected with carts and hand excavation.

Foundations. — The entire building is supported on a concrete mat approximately 6 ft. thick, reinforced in both directions with Ransome rods, the location of this reinforcing and the quantity thereof being dependent on the character and location of loads to be carried. The intake pipes pass under the boiler room at a considerable depth, and at this point the trench was back-filled wlth concrete.

The total load evenly distributed over the entire foundation is something less than 2 000 lb. per square foot, but the concentrated loads at certain points are very much in excess of that figure. These excess loads, however, are wholly or in part distributed by the concrete structure.

Intake Pipe. — The ultimate power-house development will call for four 72-in. conduits for condensing water. Two of these will be for the supply and two for the discharge. All four of these pipes have been installed through the levee, three have been installed under the boiler-room, but only one intake and one discharge have been installed in the open space between the boiler-room and the levee.

The above conduit is made up of riveted steel pipe 0.5 in. thick, made in 30-ft. lengths with flanged joints, lead gaskets being used between the flanges, and galvanized bolts being used to bolt the pipe together. All of this piping was dipped in hot compound after being completed, this compound adhering to the metal to a thickness of about $\frac{1}{16}$ in.

With a maximum velocity of 4 ft. per second it is estimated that the two pairs of conduits will handle sufficient condensing water to develop 50 000 kw.

Water jets have been installed throughout the entire length of this pipe, the purpose of which will be to assist in the removal of sand or silt which may be precipitated in the pipe. In addition to this a propeller type of circulating pump has been provided, this pump having a capacity sufficient to create a flow of from 8 to 10 ft. per second through the incoming and outgoing conduits. The valves used for closing off or sectionalizing this conduit are of the round balanced wicket type, as shown in Fig. 2.

Building. — The building above the foundation line, with the exception of window sash and frames, is composed of steel, brick, concrete and other non-combustible materials. The weights are supported entirely on a steel structure. The floors throughout are of concrete and the roof is partially of Ludowici tile and partially of book tile with composition top coating.

Boilers. — There are 12 Babcock & Wilcox boilers, each of 900 h.p. capacity (the largest ever built by that company). These are designed for 200 lb. working steam pressure and fitted with B. & W. bent tube superheaters designed to produce 150 degrees superheat under normal operation. The above boilers are arranged on the double deck plan, two rows on each deck, with the boilers facing.

Economizers. — One Sturtevant economizer, 10 tubes wide and 36 tubes long, containing approximately 5 400 sq. ft. of heating surface, is provided for each two boilers. These economizers are so arranged that the boiler gases may pass either directly to the stack or through the economizer.

Stokers. — The plant is equipped with thirty-six 300 h.p. Murphy smokeless furnaces, each 6 by 7 ft., set three in a battery under each boiler. These stokers project in front of the boilers and receive their supply of fuel by gravity from the overhead coal bunkers. The ashes and clinkers are passed through the bottom of the stoker (this motion being performed automatically) into ash hoppers directly under the furnaces. The demonstrated coal-burning capacity is 50 lb. per square foot of grate per hour.

Coal Handling. — The coal-handling plant consists of track scales, track hopper, mechanical feeder, crusher, elevator and belt conveyor. The coal as it is delivered is first weighed. It then passes on to the hopper and is dumped. It is then fed to

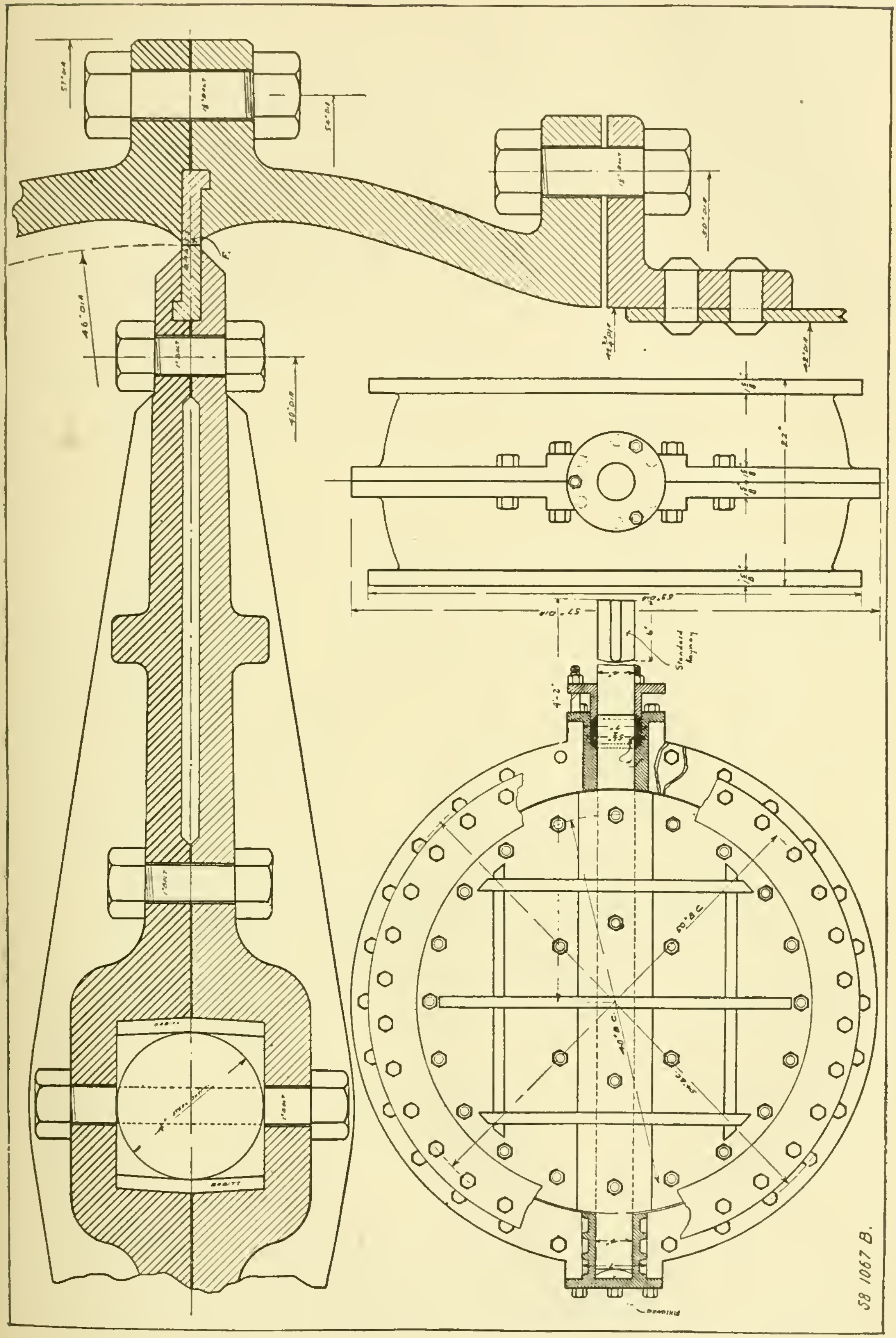


FIG. 2. WICKET VALVE.

the crusher by a mechanical feeder. It is then elevated to the top of the boiler-room structure and discharged on a belt conveyor traveling at 300 ft. per minute, which distributes it to any desired part of the coal bunker. The capacity of the coal-handling machinery is approximately 100 tons per hour.

Ash Handling. — The ashes pass from the ash hoppers under stokers down through spouts to cars operated on a tramway in the boiler-room basement. These cars are filled and then run to one end and dumped into an automatic skip which hoists them to the top of the boiler-room and discharges into an ash bunker directly above the railroad siding, from which they are removed either by cars or teams.

Stacks. — The plant is at present equipped with two self-supporting steel stacks, each 15 ft. in diameter by 273 ft. high above sidewalk level, brick lined to the roof line. The ultimate plant will call for the erection of two additional stacks of similar size.

Piping. — All high-pressure piping is full weight standard lap-welded mild steel with Van Stone joints. All fittings and valve bodies are made of cast steel and the valves have extra long necks at the stuffing boxes, designed for use with superheated steam at 200 lb. working pressure. The valves in main header and cross connections are motor operated. All boiler feed piping is of cast iron or brass and provision has been made for supplying any boiler from either of two sources.

Pumps. — Boiler feed pumps are of the Epping Carpenter make with compound steam ends, outside end packed plungers, pot valve type, designed for 250 lb. working pressure and equipped with automatic pressure-regulating governors.

Condensers. — There are at present installed one Alberger surface condenser on a 1 500 kw. turbine, two Alberger centrifugal pump jet condensers attached to two 1 500 kw. turbines and one Alberger centrifugal pump jet condenser connected to a 3 000 kw. turbine. These condensers are supplemented with dry vacuum pumps, and the equipment as a whole is designed to produce very high vacuum, this being essential, as turbines are dependent in a very great measure on high vacuum to secure economy.

Turbines. — The plant at present contains three 1 500 kw. Curtis turbines, one 3 000 kw. Curtis turbine, with one 5 000 kw. turbine of the same make on order. The above turbines are all alternating current, 60-cycle, three-phase, and are suitable for the generation of energy which may be used directly or indirectly for any service for which electricity is used.

Engines. — The station also contains two 2 250 kw. vertical engines and one 1 500 kw. vertical engine, all directly connected to railway generators. These engines have been in use for several years, and while they are operating in the same station with turbines, they may be considered the correct type of apparatus

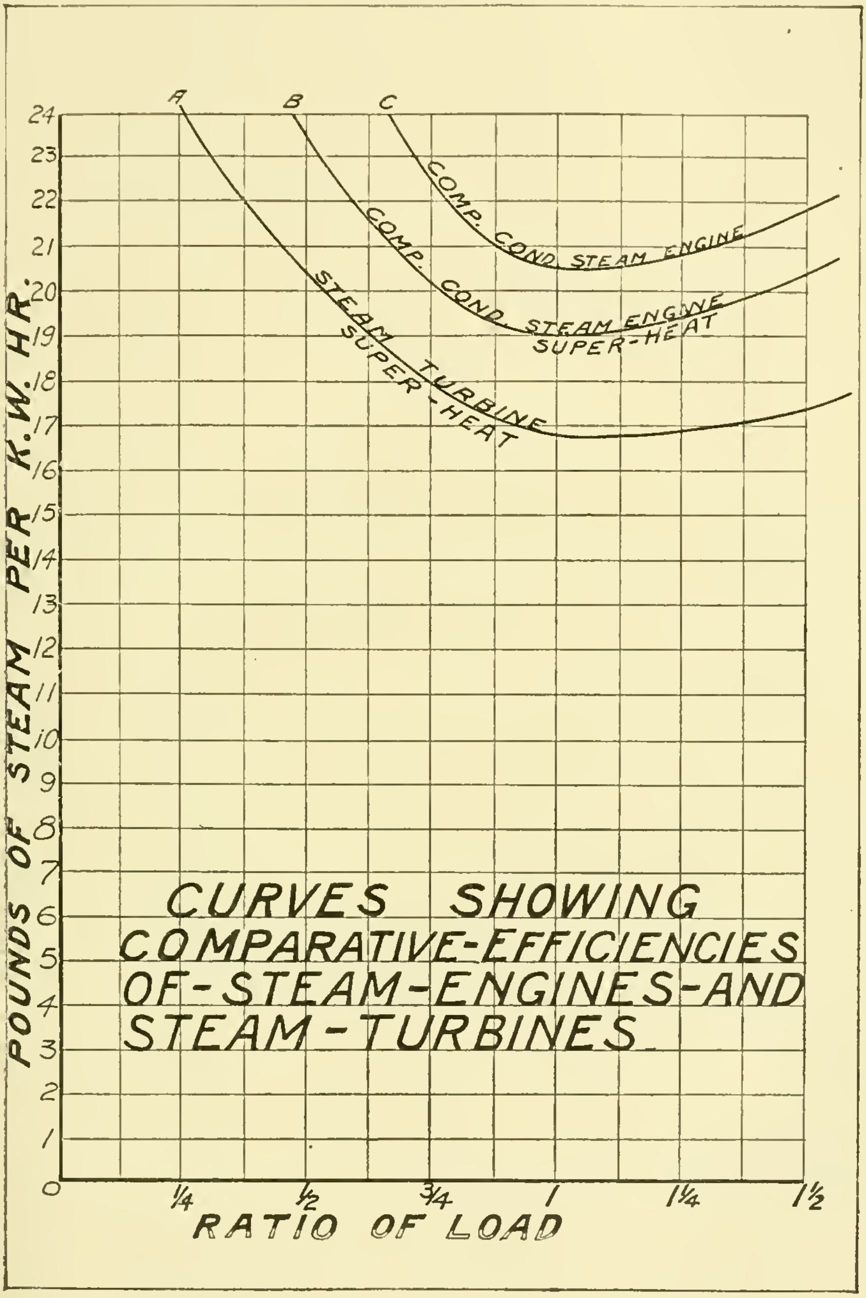


FIG. 3.

for the work they are doing. The energy could be produced by the turbines more cheaply, but that portion required for car operation would have to be transformed to direct current by means of motor generators or rotaries.

The relative economy of the steam engine and turbine is approximately indicated on accompanying chart, Fig. 3.

Switchboard. — The switchboard and control apparatus is of the most modern type. All high tension switches are of the oil-break type located in individual concrete cells and controlled from the main switchboard by means of pilot switches. The bus bars are in duplicate, in addition to which they are sectionalized. Each feeder circuit is provided with two switches, one switch connected to each set of bus bars, either one of which may be used to supply any circuit. In addition to this the principal power circuits are connected at the opposite end to either the Claiborne power station or the Baronne Street station, and in the event of an entire interruption of service at the main station these circuits may be supplied from either of these auxiliary stations, which arrangement insures the continuity and reliability of service to an unusual degree, without any expenditure for duplication of apparatus.

Claiborne Station.

The Claiborne Station as described herein consists of an extension to the old Claiborne Station, built about eight years ago, and is intended to generate current for the operation of the cars in the lower section of the city, and also as a distributing station for a. c. energy.

Pile Driving and Foundations. — This station is built on piling varying from 40 to 50 ft. in length, placed at approximately 4-ft. centers, except in certain locations, where the loads are comparatively light.

Some of this piling was set to a depth of 25 ft., but the majority of the foundation work of this station commences at about grade 27 (from 3 to 4 ft. below street level at that point). Six-inch grooved sheet piling was used to protect the deep excavations.

Intake. — The intake pipe for condensing water is 69 in. inside diameter, starts at the Southern Pacific ferry slip and terminates in the condenser pit at the power station, the center of this pipe being at grade 18.5. This pipe possesses a novel feature in that there is a creosoted wood diaphragm through the center of the pipe, the incoming water passing through the lower half and the discharge water going out through the upper half. A concrete crib was built just outside the levee, this being partitioned off to separate the incoming from the outgoing water. This structure is also used as a valve chamber, by which any one or all of the pipes terminating therein may be shut off.

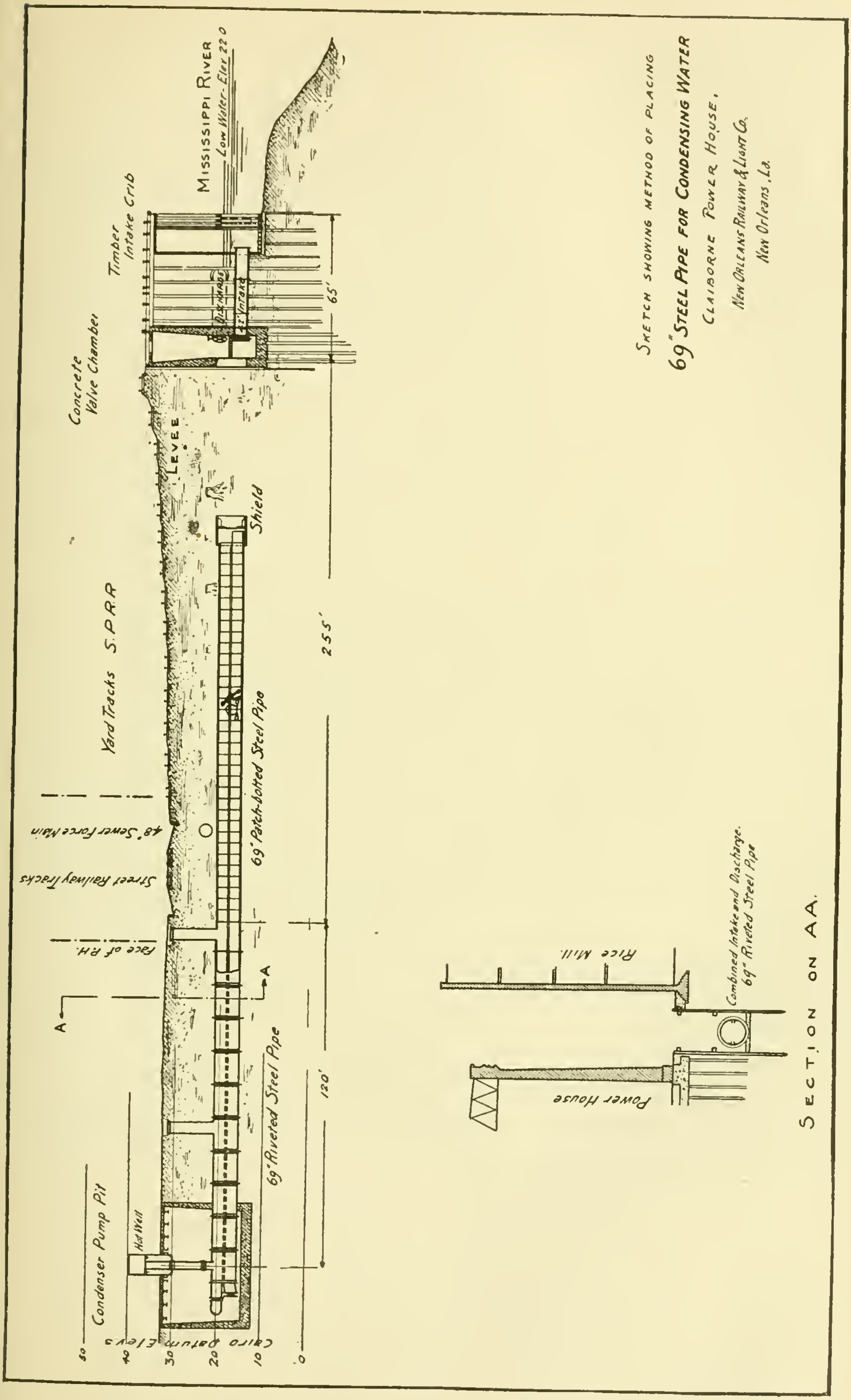

Sketch showing method of placing
69" Steel Pipe for Condensing Water
Claiborne Power House,
New Orleans Railway & Light Co.
New Orleans, La.
Mississippi River
Low Water-Elev 22.0
Timber
Intake Crib
Concrete
Valve Chamber
Levee
Shield
Yard Tracks S.P.R.R.
48" Sewer Force Main
Street Railway Tracks
Face of P.H.
69" Patch-bolted Steel Pipe
69" Riveted Steel Pipe
Condenser Pump Pit
Hot Well
Cairo Datum Elev's
50
40
30
20
10
0
65'
255'
120'
A
A
Rice Mill
Power House
Combined Intake and Discharge
69" Riveted Steel Pipe
Section on AA.

FIG. 4.

The portion of the pipe from the condenser pit to the street line consists of 15-ft. sections bolted together by means of flanges, lead joints, etc. Commencing at the street line and passing under the street railway, the Southern Pacific tracks and other obstructions, the excavating was done by the shield method and the pipe was assembled in 5-ft. rings within the shield, there being no openings to the surface and no interruption to traffic overhead during construction.

The process of laying this pipe is illustrated in Fig. 4 and some of the details of the shield and sections of pipe are also shown. The intake and discharge as installed will supply sufficient water to condense the steam from about 15 000 h.p. engine capacity.

Excavating and Earth Removal. — The most of the excavation for the Claiborne Station was comparatively shallow and was therefore taken care of by hand, the material being transported away by carts. There was one excavation approximately 20 by 60 ft. in area and about 20 ft. deep, but the bracing and other obstructions rendered anything but hand excavating out of the question.

Stack. — The new stack for this station is 11 ft. in diameter by 175 ft. high. It is located directly in the center of the new portion of the power station and would also be directly in the center of the ultimate installation in the event of its being extended. This stack is of a novel design in that the stack base consists of four steel columns stiffened with concrete and brickwork and the space directly under the stack is arched over, leaving a large passageway both on the boiler-room floor and on the basement level. One other feature is that the bottom section of the stack is square instead of round, the side sheets being riveted directly between a channel framing at the base of the stack, there being no base ring. This construction is partially shown on Fig. 5.

Machinery Foundations. — The machinery foundations are entirely of concrete, built up in the usual manner, except, however, that large arches were provided under the engine cylinders, allowing ample room for access to piping and other parts beneath the engine-room floor.

Building. — The building is a combination steel, brick and concrete construction; the engine-room walls are entirely of brick and the crane runway and roof trusses are supported by the brickwork; considerable steel was used in the boiler-room, however, for supporting the coal bunker and economizers. A

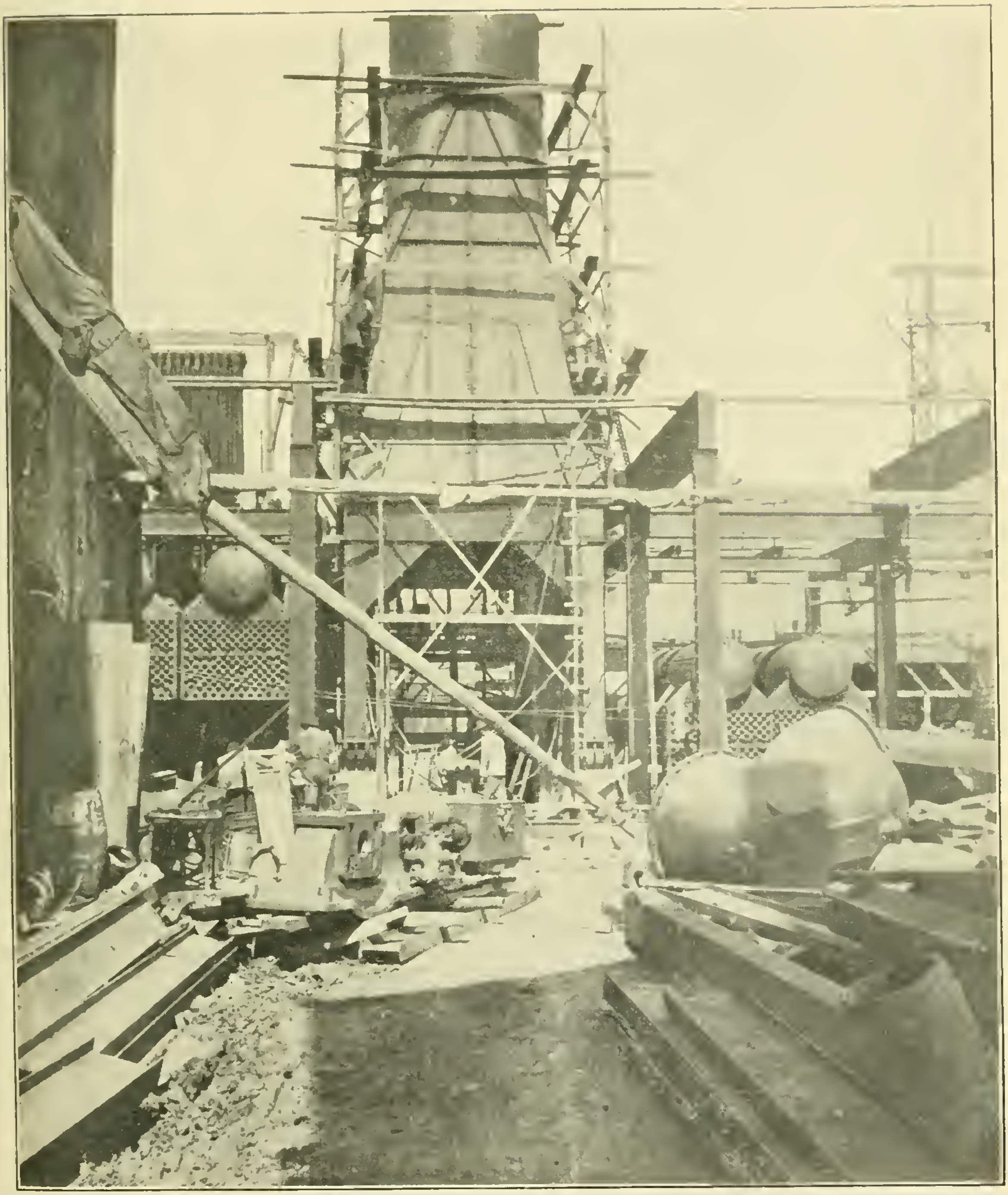


FIG. 5. CLAIBORNE STACK STEEL WORK.

fair idea of the character of the building may be obtained from Fig. 6.

The floors are of concrete throughout; the roof is also of concrete, approximately 2.5 in. thick, with a 1-in. top coating. Both engine and boiler-room roofs have ventilating monitors throughout the entire length, and the section of boiler-room roof directly over the economizers has an additional monitor which provides a free circulation of air, a very desirable feature in this climate.

Both the outside and inside engine-room walls are faced with salmen pressed brick laid in cement mortar. There are no very notable features about the building other than that it may be considered an up-to-date example of its kind and admirably adapted to southern climatic conditions.

Boilers. — There are now installed in the station four Edgemore boilers of approximately 350 h.p. each and four Heine boilers of approximately 600 h.p.each, making a total of 3 800 h.p. These are arranged in a single row facing away from the engine-room.

Stokers. — Eight 6 by 8 ft. Murphy smokeless furnaces are installed in this station, these being under the new boilers only. The stokers are rated at 300 h.p. each, two stokers being used per boiler. The ratio of heating surface per foot of grate surface is approximately 60 to 1.

Coal Handling. — The coal is delivered to the station in wagons or carts, but it is intended that it shall be later delivered in cars and discharged directly into the crusher. After passing through the crusher, the coal is elevated in a continuous bucket elevator and discharged on a 24-in. traveling belt operating at a speed of about 200 ft. per minute, and by means of this belt distributed to any part of the coal bunker. The capacity of this equipment is about 50 tons per hour.

The coal, after being delivered into the bunker, passes down through spouts to the stoker hoppers and is fed through the stokers automatically.

Ash Handling. — The ashes drop directly into concrete hoppers located under the stokers and thence to a car and conveyed to one end of the boiler-room, at which point they will be elevated by means of a skip and discharged into an overhead bunker. The dust from the furnaces and the dust from the combustion chambers will be delivered into the ash hoppers by means of screw conveyors. Therefore there will be no occasion to handle coal, ashes or dust over the boiler-room floor.

Economizers. — The station is equipped with four Sturtevant economizers, one economizer being placed over each one of the four 600 h.p. boilers. These economizers are 12 tubes wide and 10 tubes long, giving an unusually large area for gas passages through the economizer. Dampers are so arranged that by means of interlocking mechanism the economizer may be cut in or out of service by throwing a lever from the boiler-room floor, and while a boiler and an economizer constitute a single unit, any economizer may be cut out without interfering with the use of the boiler, and the requisite feed water for all of the boilers may be passed through the remaining economizers in service.

Piping. — Full-weight standard lap-welded pipe was used throughout for high-pressure steam. Van Stone joints were also used for sizes 7 in. and larger.

The main header is 12 in. diameter, sectionalized and with boiler and engine connections so arranged that any section of header may be taken down for repairs without interfering with the use of any boiler or any engine.

An auxiliary steam line supplies steam to the boiler feed pumps, circulating pumps, etc., this line receiving its supply of steam from either battery of boilers or from the main header at the rear of the boilers. The boiler feed pipe is in duplicate and is cross connected with double crosses at several points so that both systems may operate simultaneously, one handling hot water and the other cold water, or with a number of combinations. This arrangement of piping is shown briefly on Fig. 7.

Oiling System. — The oiling system consists of overhead tanks supplying oil to the engines under a gravity head, the waste oil passing through the bearings, then to a filter located in the basement and from the filter to the overhead tanks, the original starting point.

Condenser. — The plant is equipped with a 42-in. elevated barometric condenser of the Alberger type, rated at 5 000 kw. capacity. The exhaust steam from all of the engines is conveyed to the condenser through a 42-in. exhaust header.

Circulating water is taken from the bottom half of the intake pipe previously referred to, and is passed through centrifugal pumps having a capacity of 5 000 gal. per minute against a 70-ft. static head. Two of these pumps are provided, each being driven by a 12 by 16 horizontal side crank engine fitted with hand-operated cut-off gear. This form of condenser, after being started, only requires that the water be delivered to the point

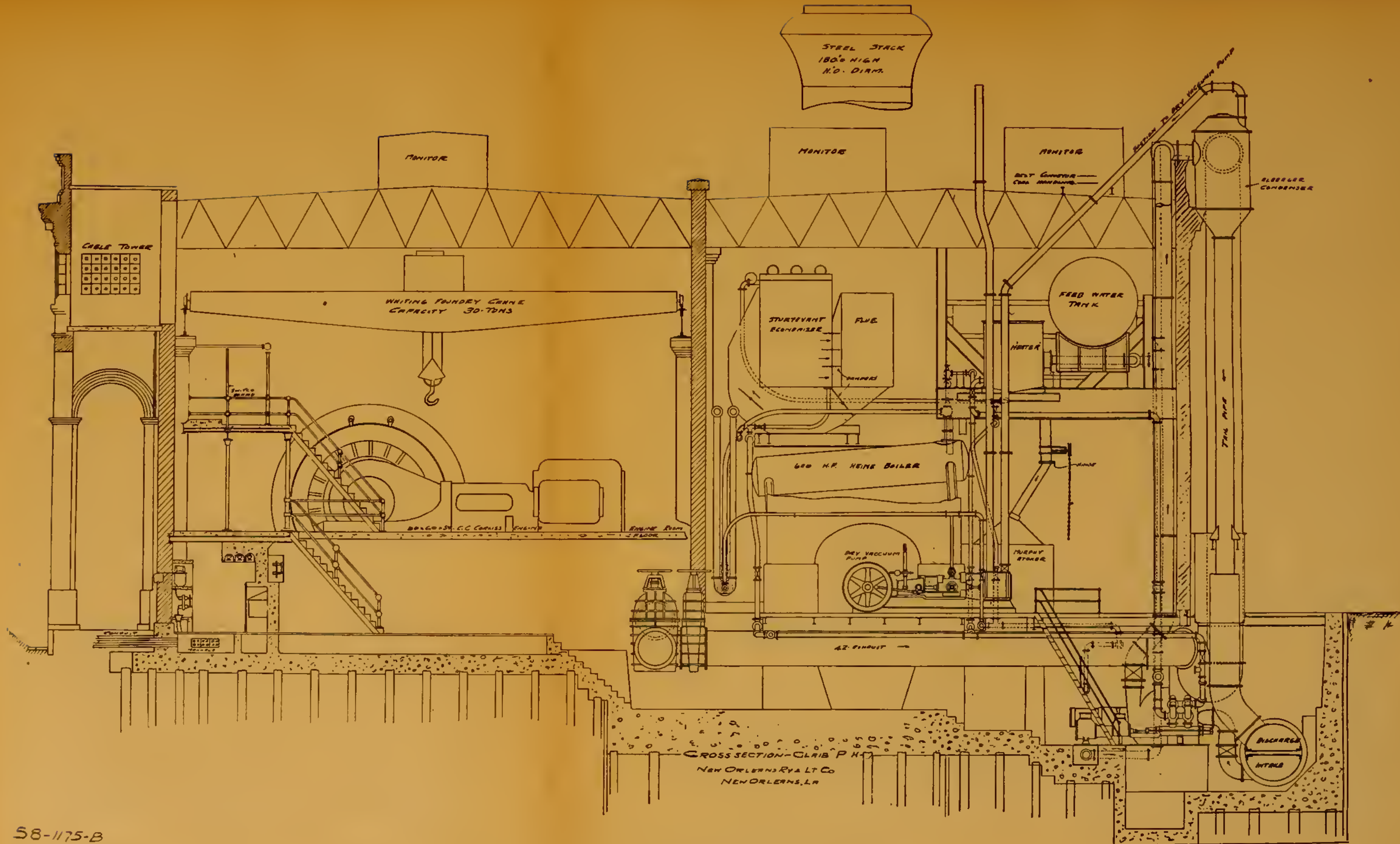


Fig. 6. Cross Section through Claiborne Power House.

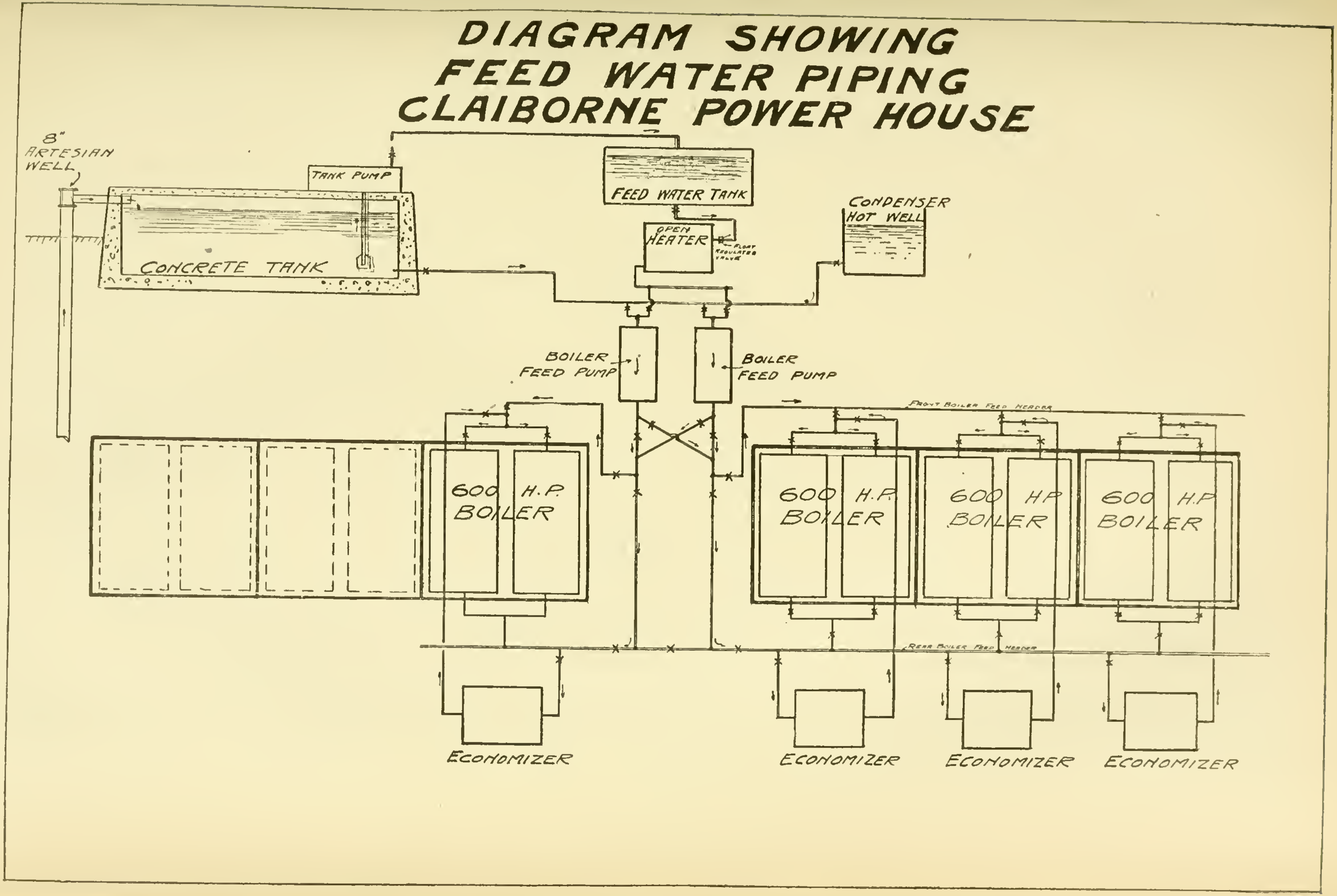


DIAGRAM SHOWING
FEED WATER PIPING
CLAIBORNE POWER HOUSE
8" ARTESIAN WELL
TANK PUMP
CONCRETE TANK
FEED WATER TANK
OPEN HEATER
FLOAT REGULATED VALVE
CONDENSER HOT WELL
BOILER FEED PUMP
BOILER FEED PUMP
FRONT BOILER FEED HEADER
600 H.P. BOILER
600 H.P. BOILER
600 H.P. BOILER
600 H.P. BOILER
REAR BOILER FEED HEADER
ECONOMIZER
ECONOMIZER
ECONOMIZER
ECONOMIZER

FIG. 7.

at which the water will flow into the vacuum without pumping against the entire static head.

This system also requires the use of a dry vacuum pump which takes care of the air leakage and is well adapted to plants of this type, where a comparatively large number of engines are operated, as it obviates the necessity for operating a separate condenser for each engine and the pumps used are less complicated than the duplex or other types frequently used.

Type of Engines. — The station will be equipped as follows:

Two 1 200 kw. Filer & Stowell cross compound engines, two 800 kw. cross compound Allis engines, two 300 kw. tandem compound Allis engines, two 500 kw. General Electric motor generators. The engine units are all direct connected, the motor generators will be used to transform alternating current received from the main station to railway current at the Claiborne Station, or to transform railway current for delivery to the lighting system or to any of the other stations.

Switchboard and Electrical. — The switchboard is mounted on an elevated gallery arranged symmetrically along the front wall of the engine-room, the railway portion being on the right and the alternating portion on the left. This station, in addition to generating railway current, will act as a distributing station and will contain the transformers and switchboard apparatus requisite for the operation of about 700 arc lamps.

All of the alternating switches in this station are of the enclosed oil break type, mounted in concrete cells and controlled by means of pilot switches on the main switchboard.

The direct current or railway switchboard controls the positive side of the generator by means of hand-operated switches and circuit breakers, but the negative and the equalizer, which in this case is on the negative side, are controlled by means of electrically operated, remote control switches, the pilot switches for their operation being mounted on the generator panels. By this means a switchboard operator may quickly and positively control all of the switches at any one or all of the eight generators without leaving the platform.

Provision has been made for either underground or overhead transmission or both. At the present time the high tension cables come into the station underground and the railway and other distributing circuits pass out overhead.

Impeller. — A 36-in. centrifugal pump has been installed at the end of the intake pipe heretofore described, the function of which will be to take water out of the upper half of the pipe and

discharge into the lower half for the purpose of washing out any sediment which may accumulate. This pump has a capacity of 40 000 gal. per minute against an 8-ft. head and is to be operated by 300 h.p. motor. It is expected that this will only be required at intervals of a week or ten days and then only for probably an hour.

Baronne Street Station.

The Baronne Street Station, known as Edison No. 1, having a capacity of about 4 000 kw. direct current and of about 1 500 kw. alternating current capacity, has been built for some years, This station will not be discussed at any great length in this paper except to say that the station is tied to the central power station electrically by means of the high tension cables and will be tied to the sub-stations electrically both from the high tension alternating current side and on the low tension direct current side with every facility for receiving current from any of the other stations and for transmitting current to any of the other stations in the event it should at any time be necessary.

This station was recently equipped with twelve 300-h.p. Murphy furnaces set in batteries of three stokers to two boilers. This proved to be a very difficult and unusual job owing to the fact that the requisite stoker capacity could not be installed under the single units. Therefore it was found expedient to install three stokers under two boilers, which necessitated supporting a portion of the center wall from the boiler girders. This installation has now been in operation over a year and has proven very satisfactory from the standpoint of efficiency, capacity, smoke abatement and economy.

Valence Sub-Station.

The Valence Sub-Station is located at the corner of Valence and Franklin streets. The ultimate installation will probably be 5 000 or 6 000 kw., but at present the equipment consists of constant current transformers and switchboard for supplying 660 arc lamps and two 500-kw. motor generator sets for the supply of railway current. This station is designed to receive 6 600-volt alternating current from the central station or from any other station via the central station and it is here transformed to railway current or any other kind of current required to meet the demand at that point.

This station presents a fair example of modern sub-station design and construction.

Algiers.

The Algiers Sub-Station, although owned and operated by other parties, receives its energy in the shape of high tension alternating current from any of the generating stations of the New Orleans Railway & Light Co., but ordinarily will receive its supply from the central station. The current delivered at the Algiers Station is used for commercial lighting, power and arc lighting and for the operation of an electric car system.

Duplicate transmission lines have been provided, the principal feature of these being the submarine cables crossing the river at Market Street and at Louisa Street. These are 00–three conductor stranded cables, insulated with rubber and protected by galvanized iron wire armor. These cables terminate in suitable cable houses located on each side of the river at the points designated, and are anchored at each shore anchorage and at three points in the river bed.

In addition to the stations referred to above there are two Edison sub-stations built within the underground district, one of which is now temporarily operating on Magazine Street near Poydras. The other is being built on Bourbon Street near the down-town load center. There is also the St. Charles power house containing 1 100 kw. of generating apparatus, the operation of which may shortly be discontinued except on special occasions; and the Napoleon Avenue power house, which has, with the exception of a few days, been out of commission for the past two and a half years.

Underground Conduit.

In connection with the power station work there has been installed for the same company about 600 000 ft. of underground conduit, designed for electrical service, together with approximately 150 manholes. The design, furnishing and erection of about 500 ornamental iron arc lamp poles have also been completed.

The arc lamp poles are of special design, incorporating features requisite to meet the local conditions.

The conduit requirements in this city are somewhat out of the ordinary on account of the local conditions, and for this reason it was deemed expedient to adopt a special construction throughout. The system installed consists of fiber conduit surrounded by gravel concrete laid with 1 in. of concrete between ducts and approximately 4 in. on the outside of ducts, the whole being inclosed in cypress troughs or boxes.

The manholes are built of molded concrete blocks of a special design, combining the following features:

1. They are practically watertight.

2. They may be built more quickly than brick and are stronger and more sightly after they are built.

3. The design incorporates a shelf for the support of the cables, which also acts as a barrier and which serves to prevent electrical arcs being communicated from one cable to another in the manhole.

This type of manhole has been compared only with brick, owing to the impracticability of a monolithic construction of manholes on account of the variety of shapes desired and on account of the obstructions and inability to recover and use the forms repeatedly.

Arc Lamps.

The arc light system provided for the city lighting consists of approximately 3 000 series alternating enclosed arc lamps as called for by the specifications of the city. These possess some unusual features. It was found that the ordinary commercial arc lamp would not comply with the conditions set forth in the city specifications and an entirely new design of lamp had to be provided. This lamp is operated normally at 7.8 amperes instead of 7.5, and at 87 volts pressure instead of about 72, in the ordinary lamp.

DISCUSSION.

Q. By Mr. Lawes. — What is your idea as to the comparative merits of multi-phase and single-phase electric systems?

A. The single-phase current is ordinarily only suitable for light or for small motors, except that low-frequency alternating single-phase current is now being extensively used in interurban railway motors recently brought out by the different electrical companies. Single-phase railway motors are now being built of 25-cycle frequency, operating on either alternating or direct current. For that reason, in order to provide a system from which we can operate any kind of service, it is desirable to install either the two-phase or three-phase system, and the three-phase is the simplest and most commonly used. Any kind of electrical apparatus that has been so far offered may be operated from the three-phase system through the medium of transformers and converters.

Q. Reduced to single-phase?

A. No; to change the voltage or frequency. The single-phase system is only applicable to special railway motors and this type is used principally in interurban work where stops are infrequent.

Q. By Mr. Wood. — How do you remove silt from the intake pipes?

A. By means of the circulating pumps or impellers, the function of these being to propel the water from one pipe into the other. The pump in central station may operate in either direction and is intended to create a head of only 8 or 10 ft.

Q. At what time would you have to take it in opposite direction?

A. In case the strainers get stopped up, the direction of flow could be changed; this would tend to clean them.

Q. How is the impeller driven?

A. By means of a 700-h.p. motor.

Q. The plant will have to run non-condensing, of course, when you are cleaning out pipes?

A. Not necessarily. The impeller pump is designed to circulate twice as much water as the plant will consume, and while the temperature of the water will rise, it would still give a fair vacuum.

Q. Do you anticipate serious trouble from silting?

A. We have had an experience at the Claiborne Station. We had a pipe installed and it remained idle for something like five months and filled up absolutely solid for about 40 ft. in length. When we were ready to start we simply opened the valve and the flow commenced. I am not nearly as apprehensive about these things as I was. There is sure to be a certain amount of deposit in such pipes, but it is only a question of getting up a sufficient circulation to get it out. We figure that if the silt was carried in at a certain velocity, it would certainly require more than that to get it out. That is what the impellers have been provided for.

Q. Will that water be flowing at all times — will it not be stationary at times?

A. There will always be some water going through. We figure that the present demands do not call for more than one half of the area of one of these pipes. The flow will therefore be very slow and the pipes will probably silt up to a certain point, but there is not a particle of danger of an entire stoppage.

Q. What were the features influencing the selection of steel stacks?

A. Better looking, stronger, occupy less space and cheaper, taking into consideration cost of foundations.

Q. Is there much danger of stack getting out of plumb in this country?

A. Here in New Orleans I should say not. One consideration that has favored the building of steel stacks has been their ability to resist high wind velocities.

Q. Are your steel stacks lined?

A. They are lined to the roof line only.

Q. Don't you consider the fact that a steel stack has to be painted very often quite a drawback?

A. That was taken into consideration. Painting does not prove to be a serious factor, requiring on an average painting a stack about every two years, and the cost of painting is very slight.

Q. What is the life of a steel stack?

A. I do not think anybody has found out. I do not know of any large steel stack that has been used continuously that has deteriorated, except around the ornamental hood. If a steel stack is used continuously I don't think there will be any corrosion inside, and if it is painted when it needs it, I don't think there will be much on the outside. If steel stacks are in use only intermittently they will deteriorate very rapidly near the top.

Q. Are these stacks all calked?

A. None of them are calked.

Q. Which way do you let your joint lap?

A. The laps are made so that the water will drain on the outside.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1907, for publication in a subsequent number of the Journal.]

REPORT OF THE SPECIAL COMMITTEE ON REINFORCED CONCRETE OF THE ENGINEERS' CLUB OF ST. LOUIS EMBODIED IN THE BUILDING ORDINANCES OF THE CITY OF ST. LOUIS.

Specifications for Reinforced Concrete Structures.

[Discussed by members of the Club, May 17, 1907.]

Definitions.

Reinforced Concrete

1. Reinforced concrete is a concrete in which steel is embodied in such manner that the two act in unison in resisting stresses due to external loading.

Concrete

2. Concrete is an artificial stone resulting from a mixture of Portland cement, water and an aggregate.

Portland Cement

3. Portland cement shall be as defined in the Standard Specifications, adopted on June 14, 1904, by the American Society for Testing Materials.

Aggregates

4. An aggregate, as herein used, means one or more of the following materials: sand, broken stone, gravel, hard burned clay. Aggregates will be divided into two classes, fine aggregates and coarse aggregates. A fine aggregate will include all aggregate passing a No. 8 sieve. A coarse aggregate will include all aggregate passing a 1-in. ring and retained on a No. 8 sieve.

Quality of Materials.

Portland Cement

5. Portland cement shall conform to the requirements of the specifications of the American Society for Testing Materials, as adopted June 14, 1904, with all subsequent amendments thereto.

Grading of Aggregates

6. Aggregates — fine aggregates shall be well graded in size from the finest to at least the size retained on a No. 10 sieve. Coarse aggregates shall also be well graded in size from the finest to at least the size retained by a $\frac{9}{16}$-in. ring. Fine aggregates may contain not more than 5 per cent., by weight, of clay, but no other impurities. Coarse aggregates shall contain no impurities.

Sand

7. Sand shall be equal in quality to the Mississippi River sand.

Broken Stone

8. Broken stone shall be either limestone, chatts, or granite, or some other stone equal to one of these in the opinion of the Commissioner of Public Buildings.

9. Hard burned clay shall be made from suitable clay free from sand or silt, burned hard and thoroughly. Absorption of water should not exceed 15 per cent. **Hard Burned Clay**

10. *Concrete.* — The solid ingredients of the concrete shall be mixed by volume in one of the following proportions: **Proportion of Concrete**

(*a*) Not more than three parts fine aggregate to one of cement.

(*b*) Not more than two parts of fine aggregate and four parts of coarse aggregate to one of cement, but in all cases the fine aggregate shall be 50 per cent. of the coarse aggregate.

11. Concrete shall have an ultimate strength in compression in 28 days of not less than the following: **Strength of Concrete**

Burned clay concrete — 1 000 lb. per square inch.

All other concrete — 2 000 lb. per square inch.

12. Steel shall be medium steel or high elastic limit steel. The physical properties shall conform to the following limits: **Physical Properties of Steel**

	Medium Steel.	High Elastic Limit Steel.
Elastic limit,	Not less than 30 000.	Not less than 50 000.
Percentage of elongation, min. in 8 in.,	$E = \frac{1\,800\,000}{f - 10\,000} - 10.$	$E = \frac{1\,800\,000}{f - 10\,000} - 10.$
Cold bend without fracture on outer circumference,	180 degrees flat.	90 degrees to radius = 5 times thickness.
Character of fracture,	Silky.	Silky or fine granular.

f = unit stress in steel at ruptures.

13. Tests shall be made on specimens taken from the finished bar, and certified copies of test reports shall be furnished the Commissioner of Public Buildings at his request. **Test Specimens of Steel**

14. Bending tests shall be made by pressure. **Bending Tests**

15. Finished material shall be free from seams, flaws, cracks, defective edges or other defects, and have a smooth, uniform and workmanlike finish, and shall be free from irregularities of all kinds. **Finished Steel**

16. The net area of cross-section of finished steel members shall not be less than 95 per cent. of the area shown in the approved design. **Minimum Finished Section**

Execution.

17. All reinforced concrete work shall be built in accordance with approved detailed working drawings. These drawings shall be submitted to the Commissioner of Public Buildings for ap- **Drawings**

proval, and no work shall be commenced until the drawings shall have been approved by him.

Condition of Surface of Steel

18. The steel used for reinforcing concrete shall have no paint upon it, but shall present only a clean or slightly rusted surface to the concrete. All dirt, mud and other foreign matter shall be removed.

Cleaning Steel

19. If the steel has more than a thin film of rust upon its surface it shall be cleaned before placing in the work.

Unit Measure of Cement

20. In proportioning materials for concrete, one bag containing not less than 93 lb. of cement shall be considered 1 cubic foot.

Mixing Concrete

21. The ingredients of the concrete shall be so thoroughly mixed that the cement shall be uniformly distributed throughout the mass and that the resulting concrete will be homogeneous.

Wetness and Placing of Concrete

22. The concrete shall be mixed as wet as possible without causing a separation of the cement from the mixture, and shall be deposited in the work in such manner as not to cause the separation of mortar from coarse aggregate.

Placing Concrete

23. Concrete shall be placed in the forms as soon as practicable after mixing, and in no case shall concrete be used if more than 1 hr. has elapsed since the addition of its water. It shall be deposited in horizontal layers not exceeding 8 in. in thickness and thoroughly tamped with tampers of such form and material as the circumstances require.

Placing Steel

24. The steel shall be accurately placed in the forms and secured against disturbance while the concrete is being placed and tamped, and every precaution shall be taken to insure that the steel occupies exactly the position in the finished work as shown on the drawing.

Location of Joints

25. Before the placing of concrete is suspended the joint to be formed shall be in such place and shall be made in such manner as will not injure the strength of the completed structure.

Joining Old and New Work

26. Whenever fresh concrete joins concrete that has set, the surface of the old concrete shall be roughened, cleaned and thoroughly slushed with a grout of neat cement and water.

Freezing Weather

27. No work shall be done in freezing weather, except when the influence of frost is entirely excluded.

Protection of Structural Parts

28. Until sufficient hardening of the concrete has occurred, the structural parts shall be protected against the effects of freezing, as well as against vibrations and loads.

Protection of Concrete from Drying

29. When the concrete is exposed to a hot or dry atmosphere special precautions shall be taken to prevent premature drying by keeping it moist for a period of at least 24 hours after it has

taken its initial set. This shall be done by a covering of wet sand, cinders, burlap, or by continuous sprinkling, or by some other method equally effective in the opinion of the Commissioner of Public Buildings.

30. If, during the hardening period, the temperature is continually above 70 degrees fahr., the side forms of concrete beams and the forms of floor slabs up to spans of 8 ft. shall not be removed before four days; the remaining forms and supports not before ten days from the completion of tamping. **Removal of Forms during Warm Weather**

31. If, during the hardening period, the temperature falls below 70 degrees fahr., the side forms of concrete beams and the forms of floor slabs up to spans of 8 ft. shall not be removed before seven days; the remaining forms and the supports not before fourteen days from the completion of the tamping. But if, during the hardening period, the temperature falls below 35 degrees fahr., the time for hardening shall be extended by the time during which the temperature was below 35 degrees fahr. **Removal of Forms during Cold Weather**

32. Forms for concrete shall be sufficiently substantial to preserve their accurate shape until the concrete has set, and shall be sufficiently tight so as not to permit any part of the concrete to leak out through cracks or holes. **Forms**

33. Before placing the concrete, the inside of the forms shall be thoroughly cleaned of all dirt and rubbish, the forms of all beams, girders and columns being constructed with a temporary opening in the bottom for this purpose. **Cleaning Forms**

34. If loading tests are considered necessary by the Commissioner of Public Buildings, they shall be made in accordance with his instructions, but the stresses induced in all parts of a structural member by its test load shall be the same as if the member were subjected to twice the dead load plus twice the assumed load. **Loading Tests**

35. All tests of material herein required shall be made by testing laboratories of recognized standing, and certified copies of such test reports shall be filed with the Commissioner of Public Buildings. **Tests of Materials**

Design.

36. The weight of burned clay concrete, including the steel reinforcement, shall be taken at 120 lb. per cubic foot. **Weight of Burned Clay Concrete**

37. The weight of all other concrete, including the reinforcement, shall be taken at 150 lb. per cubic foot. **Weight of Other Concrete**

38. Besides the above, in calculating the dead loads, the weights of the different materials shall be assumed as given in Table No. I. **Weights of Materials**

TABLE No. I.

WEIGHTS OF BUILDING MATERIALS, ETC., IN POUNDS PER CUBIC FOOT.

Material.	Weight.	Material.	Weight.
Paving brick	150	Plaster	140
Building brick	120	Glass	160
Granite	170	Snow	40
Marble	170	Spruce	25
Limestone	160	Hemlock	25
Sandstone	145	White pine	25
Slag	140	Oregon fir	30
Gravel	120	Yellow pine	40
Slate	175	Oak	50
Sand, clay and earth	110	Cast iron	450
Mortar	100	Wrought iron	480
Stone concrete	150	Steel	490
Cinder concrete	90	Paving asphaltum	100

Live Loads

39. The following table gives the uniformly distributed live loads for which structural members shall be designed when their dead loads are as given in the first column, A:

TABLE No. II.

DEAD LOAD. POUNDS PER SQUARE FOOT. (Column A.)	CORRESPONDING LIVE LOAD. POUNDS PER SQUARE FOOT. (1)	(2)	(3)	(4)
40 or under	72	103	155	194
50	63	93	140	175
60	59	84	126	158
70	53	76	114	143
80	48	69	104	130
90	46	64	96	120
100	41	58	87	109
110	37	53	80	100
120	34	49	74	93
130	31	44	66	81
140	29	41	62	78
150 or over	27	39	59	74

Dwellings, Etc.

40. The live loads on floors for dwellings, apartment houses, dormitories, hospitals and hotels shall be as given in column 1 of Table No. II.

Schoolrooms, Etc.

41. For schoolrooms, churches, offices, theater galleries, use column 2, Table No. II.

Stores, Etc.

42. For ground floors of office buildings, corridors and stairs in public buildings, ordinary stores, light manufacturing establishments, stables and garages, use column 3, Table No. II.

Assembly Rooms, Etc.

43. For assembly rooms, main floors of theaters, ball-rooms,

gymnasiums or any room likely to be used for dancing or drilling, use column 4, Table No. II.

Sidewalks

44. For sidewalks, 300 lb. per square foot.

Warehouses, Etc.

45. For warehouses, factories, special according to service, but not less than column 4 of Table No. II.

Columns

46. For columns the specified uniform live loads per square foot shall be used with a minimum of 20 000 lb. per column.

Reduction on Columns

47. For columns carrying more than five floors the live loads may be reduced as follows:

For columns supporting the roof and top floor, no reduction.

For columns supporting each succeeding floor, a reduction of 5 per cent. of the total live load may be made until 50 per cent. is reached, which reduced load shall be used for the columns supporting all remaining floors.

Exceptions to Reduction on Columns

48. This reduction is not to apply to live load on columns of warehouses and similar buildings which are likely to be fully loaded on all floors at the same time.

Theory of Stresses

49. The method used in computing the stresses shall be such that the resultant unit stresses shall not exceed the prescribed unit stresses as computed on the following assumptions:

(1) That a plane section normal to the neutral axis remains such during flexure, from which it follows that the deformation in any fiber is directly proportionate to the distance of that fiber from the neutral axis.

(2) That the modulus of elasticity remains constant within the limits of the working stresses fixed in these regulations and is as follows:

Steel, 30 000 000 lb. per square inch.
Burnt clay concrete, 1 500 000 lb. per square inch.
All other concrete, 2 000 000 lb. per square inch.

(3) That concrete does not take tension, except that in floor slabs, secondary tension induced by internal shearing stresses may be assumed to exist.

Unit Stresses.

Unit Working Stresses

50. The allowable unit stresses under a working load shall not exceed the following:

Burned clay concrete:

Direct compression, 300 lb. per square inch.
Cross bending, 400 lb. per square inch.
Direct shearing, 150 lb. per square inch.
Shearing where secondary tension is allowed, 15 lb. per square inch.

All other concretes:

Direct compression, 500 lb. per square inch.

Cross bending, 800 lb. per square inch.

Direct shearing, 300 lb. per square inch.

Shearing where secondary tension is allowed, 25 lb. per square inch.

STEEL.

	Medium Steel.	High Elastic Limit Steel.
Tension	14 000	20 000

Compression in Steel 51. The compression in the steel shall be computed from the corresponding compression in the concrete, except for hooped columns.

Bonding Stress — Plain Bars 52. The bonding stress between steel and concrete under working load shall not exceed the following for plain steel:

For medium steel, 50 lb. per superficial square inch of contact.

For high elastic limit steel, 30 lb. per superficial square inch of contact.

Bonding Stress Other than Plain Bars 53. For bars of such shape throughout their length that their efficiency of bond does not depend upon the adhesion of concrete to steel, the allowable bonding stress under working load shall be determined as follows:

The bars shall be imbedded not less than 6 in. in concrete as herein defined, and the force required to pull out the bar shall be ascertained. At least five such tests shall be made for each size of bar and an affidavit report of the test shall be submitted to the Commissioner of Public Buildings, who shall then fix one fourth of the average stress thus ascertained at failure as the allowable working stress.

Maximum Column Length 54. The unsupported length of a column shall not exceed fifteen times its least lateral dimension.

Combined Flexure and Compression 55. In a column subjected to combined direct compression and flexure, the extreme fiber stress resulting from the combined actions shall not exceed the unit stress prescribed for direct compression.

Reinforcement in Columns 56. All columns shall have longitudinal steel members so arranged as to make the column capable of resisting flexure. These longitudinal members shall be stayed against buckling at points whose distance apart does not exceed twenty times the least lateral dimension of the longitudinal member. In no case shall the combined area of cross-section of these longitudinal members be less than 1 per cent. of the area of the concrete used

in proportioning the column, and the stays shall have a minimum cross-section of three one-hundredths of a square inch (0.03 sq. in.)

57. If a concrete column is hooped with steel near its outer surface either in the shape of circular hoops or of a helical cylinder, and if the minimum distance apart of the hoops or the pitch of the helix does not exceed one tenth the diameter of the column, then the strength of such a column may be assumed to be the sum of the following three elements: **Hooped Columns**

(1) The compressive resistance of the concrete when stressed not to exceed 500 lb. per square inch for the concrete inclosed by the hooping, the remainder being neglected.

(2) The compressive resistance of the longitudinal steel reinforcement when stress does not exceed allowable working stress for steel in tension.

(3) The compressive resistance which would have been produced by imaginary longitudinals stressed the same as the actual longitudinals; the volume of the imaginary longitudinals being taken at two and four-tenths (2.4) times the volume of the hooping. In computing the volume of the hooping it shall be assumed that the section of the hooping throughout is the same as its least section. If the hooping is spliced the splice shall develop the full strength of the least section of the hooping.

58. The minimum covering of concrete over any portion of the reinforcing steel shall be as follows: **Minimum Covering of Steel**

For flat slabs, not less than one inch.

For beams, girders, ribs, etc., not less than 1.5 in.

For columns, not less than 2 in. In computing the strength of columns, other than hooped columns, the outside one inch around the entire column shall be neglected.

59. For flat slabs continuous over two or more supports and uniformly loaded, the bending moment may be taken as $\frac{WL}{12}$ in which W equals total load on the span and L the center to center distance between supports. **Continuous Slabs**

60. Beams continuous over supports shall be reinforced to take the full negative bending moment over the supports, but shall be computed as non-continuous beams. **Continuous Beams**

61. The minimum distance center to center of reinforcing steel members shall not be less than the maximum diameter or diagonal dimensions of cross-section plus 2 inches. **Minimum Spacing of Steel**

62. In designing T-beams, the width of floor slab which may be assumed to act as compression flange of the beam shall not **T-Beams**

Splicing Steel

exceed one fourth of the span of the beam, but in no case shall it exceed the distance, center to center, of beams.

63. If it is necessary to splice steel reinforcing members, either in compression or tension, the splice shall be either a steel splice that in tension will develop the full strength of the member, or else the members shall be lapped in the concrete for a length equal to at least the following: For plain bars of medium steel, forty times the diameter or maximum diagonal of cross-section. For plain bars of high elastic limit steel, seventy times the diameter or maximum diagonal of cross-section. For other than plain bars, the length of lap shall be in inverse ratio to the ratio of the allowed bonding stresses as herein required. In no case, however, shall the steel reinforcement in a beam or girder be lap spliced.

DISCUSSION.

Mr. Charles K. Traber (*by letter*). — I should like to say a few words regarding one of the definitions:

Paragraph 8 states, " Broken stone shall be either limestone, chatts, or granite, or some other stone equal to one of these in the opinion of the Commissioner of Public Buildings."

Being located in the "lead belt" of St. Francis County, only 65 miles from St. Louis, from which section all the chatts which would be used in St. Louis would necessarily come, I can give a little information concerning the properties of these "chatts." The material which forms the gangue in which the lead sulphide occurs is a very soft limestone, which disintegrates rather rapidly when exposed to the elements. The tailings from the concentrating mills, composed entirely of this limestone, are what are commonly known as "chatts." This district produces perhaps a hundred cars daily of these chatts, and with the exception of a small fraction taken by the railroads for ballast, it is all thrown on the dump.

All the larger mills now crush their ore to pass through a screen with 6 mm., or less than 0.25 inch openings. The greater part of the chatts is, however, very much finer than this. Probably 90 per cent. would pass through a No. 8 sieve. I have made some tests of this material and have found that the percentage of voids is about the same as for ordinary unscreened river sand. The chatts absorb a great deal of water, however, as a considerable proportion is in the form of a fine powder.

Chatts have been used extensively in this vicinity for the foundations of houses. For this purpose they are usually mixed in the proportion of 1 to 4. This makes a fairly good concrete,

but is not economical and is used only because the chatts are at hand and cost nothing. We have found that it is much more economical to crush rock for the coarse aggregate and to use chatts for the fine, as a substitute for sand. We are now placing some very heavy foundations for mill machinery and engines, and are using a mixture of one part cement, two parts chatts and four parts broken stone, which makes a very good concrete for this purpose. We are also putting in some reinforced floors, to carry concentrating tables, and after careful consideration have decided to use sand as the fine, and broken stone as the coarse, aggregate, although the sand must be brought from some distance at considerable expense.

Chatts can hardly be classified as either coarse or fine aggregate, and should not, I think, be included in paragraph 8. It should not, in my opinion, be used at all in reinforced work.

Mr. C. D. Purdon. — The writer hesitates to discuss a specification which has already become a law by being incorporated in the building ordinances. As discussion has been invited, he offers the following remarks:

In the definitions he suggests placing the second clause first, first defining concrete and next reinforced concrete.

In clause 4 the word "aggregate" occurs too often; he would suggest that it read, "Aggregate, as herein used, shall mean one or more of the following materials: sand, broken stone, gravel, hard burned clay. Aggregates shall be divided into two classes, fine and coarse. Fine aggregate will include all material passing through a No. 8 sieve, coarse all passing through a 1-in. ring and retained on a No. 8 sieve."

Section 6, third line, transpose the words "shall" and "also" so as to read, "Coarse aggregates also shall be well graded, etc."

Section 7. Add the words "as used in St. Louis."

Section 8. The word "chatts" is indefinite. The tailings from the lead mines at Joplin are excellent, those from Galena (Kan.) contain a good deal of clay, but those from the district immediately south of St. Louis are very different, and the writer doubts very much that they would make good concrete; all of the above are called "chatts."

Section 9. He suggests that samples of the hard burned clay be submitted to the Commissioner of Public Buildings for approval.

Section 12. Add the words "pounds per square inch" to the elastic limit.

Section 15. It does not seem necessary to insist upon a smooth finish for the steel, as a great part of its value is the bond it makes with the concrete.

Section 16 is vague. Section 17 provides that the work must be built in accordance with approved drawings, and 16 seems to set this provision aside; he would suggest that 16 read "not less than 95 per cent. of the area required by calculation."

Section 17. He would suggest that it read, "All reinforced concrete work shall be built in accordance with detail working drawings which have been approved by the Commissioner of Public Buildings."

Section 18. Omit "the" in first line, and "shall" and "only" in second line.

Section 21. Shorten so as to read, "The ingredients of the concrete shall be so thoroughly mixed that the resulting mass will be homogeneous."

Section 22. Omit the word "shall" in second line.

Section 23. Omit the words "shall concrete" in second line.

Section 24. He suggests that it read, "Steel shall be accurately placed in the form and secured against disturbance during the placing and tamping of the concrete; every precaution must be taken to insure its occupying in the finished work the position shown in the drawing."

Sections 25 and 26 might be consolidated and read, "When necessary to suspend the placing of concrete, the surface shall be left in such condition as to form a joint which will not impair the strength of the completed structure, and on resuming work this surface shall be made rough, cleaned and thoroughly slushed with a grout of neat cement."

Section 27. He suggests that it read, "No concrete shall be placed in freezing weather unless it be protected from the effect of frost."

Section 29. He suggests that it read, "When concrete is exposed to a hot or dry atmosphere special precautions shall be taken to keep it moist for at least 24 hours after initial set has occurred, by a covering of wet sand," etc.

Sections 30 and 31 might be consolidated and read, "If the temperature remains above 70 degrees fahr., the side forms of beams and the forms of floor slabs up to spans of 8 ft. shall remain in place four days after initial set has occurred, the remaining forms and supports, ten days. Should the temperature fall below 70 degrees fahr., these periods shall be respectively

seven and fourteen days; and should it fall below 35 degrees fahr., these last periods shall be extended an amount equal to the time during which the temperature remained below 35 degrees fahr."

Section 32. He suggests that it read, "Forms shall be substantial enough to preserve accurate shape until the concrete has set, and sufficiently tight to prevent any part of the concrete leaking out."

Section 33. He suggests it read, "All forms shall be constructed in such a manner as to allow of their being thoroughly cleaned, which must be done before any concrete is placed in them."

Section 34. He suggests it read, "Should the Commissioner of Public Buildings require loading tests to be made, they shall be made under his instructions and in such a manner as to produce stresses double those for which the member was designed."

Section 39, the writer understands, is intended to vary the live load with the span of floor, making, in fact, an allowance for impact, as is done in bridges. It certainly is anything but clear to the writer, the first impression conveyed by it being that the stronger the floor is made the less load it will carry; while this section may produce the desired result, it seems a roundabout way of specifying it; it would be clearer to the writer were the live load varied with the length of span or area of floor.

Section 45. He suggests it read, "For warehouses and factories special loading according," etc.

Section 49, clause 3. Read, "except in floor slabs, when secondary," etc.

Section 50. Two of the unit stresses for burned clay concrete are made one half of these for "all other concretes"; why should not the direct compression follow the same ratio?

Section 53 should provide some limit of time before making the test.

Section 58. Omit either the word "minimum," in the first line, or the words "not less than," in the third, fourth and fifth lines.

Section 60. Insert "otherwise" after "shall" in the second line.

Section 61. Omit "minimum" in first line.

Section 62. Omit "which may be" at end of first line.

Mr. A. E. Lindau. — Eternal vigilance is the keynote to success in the execution of reinforced concrete structures. The physical properties of materials used in the construction can

and should be tested at intervals during the progress of the work, but the placing of the concrete and handling of the reinforcement are dependent entirely upon proper supervision and upon the skill of the workmen.

There can be no question of the fact that the erection of reinforced concrete work presents a very serious problem at the present time. Other building materials are the product of nature's workshop or highly skilled manufacturing establishments, while the strength of concrete is a function of that most variable quantity, skilled labor. In fact, we do not enjoy the advantages offered by skilled labor in other types of building work. There is not comparison beween a good carpenter and a concrete worker as far as knowledge of the strength and proper proportion of their respective materials is concerned.

The demand for skilled workmen in the manipulation of concrete material has been recognized in some of the larger cities, to the extent of organizing or unionizing the labor, but thus far the increase in wages has not been accompanied by a relative increase in the efficiency of the labor. Ordinarily, when concrete is to be placed, a gang of men is organized, some of them having no experience whatever; by patience and unceasing effort they may be made to understand what is required after a few days, but just about that time the concreting has caught up with the carpenters, the force must be "laid off," only to be reorganized later. Consequently the skill that might be developed on work of some magnitude is denied us, and the problem is invariably reduced to one of supervision.

Reinforced concrete engineers are painfully aware of the fact that bids on their designs are as likely to be awarded to contractors who have never attempted reinforced concrete work before as to those having years of experience. To the credit of such contractors, however, it must be said that frequently they arrange to have some competent man in charge; if so, well and and good, but the possible lack of proper supervision should be guarded against by securing and organizing a sufficient number of reliable and experienced inspectors, who would see to it that ordinances and specifications are carried out.

Testing.

The proposed ordinance provides amply for the tests of materials required in the construction, but leaves the matter of loading the actual structure to the discretion of the Building Commissioner. It would seem as though it were more important

to test the structure than the materials of which it is made. And the very fact that the work must be tested, pass examination, as it were, would exert a healthy influence on the individuals responsible for the construction. In addition, tests would check the plan examiner's work, and curb the tendency to "shave" the design, by firms interested in the sale of materials. In fact, the establishment by the city of a testing plant or station where various forms of construction could be tested to destruction would aid in clearing the atmosphere of much of the mystery with which so many systems are surrounded.

Unit Stresses.

The allowable unit stresses seem too high for both the high and low carbon steel, and many engineers would consider 800 lb. per square inch in the concrete too high, particularly in view of the fact that the average ultimate strength of 1: 2: 4 concrete reported by experimenters during the year has averaged below 2 000 lb. This, however, was concrete hand mixed; with machine mixing, better results can be obtained. In a series of tests arranged from samples of concrete being placed in the Butler Building, 7 by 7 by 7 in. cubes gave 2 310, 2 260 and 1 340 at thirty days, while for sixty days 2 900, 2 350, 3 000 were obtained, amply justifying 800 lb. for working load. But 14 000 and 20 000 in the steel would give a factor of safety of about 2.5 or 3 on the ultimate, depending upon the strength of the concrete.

In order to determine, if possible, from experiment, the relation between stress in the steel and concrete, as well as the carrying capacity of the beam at the specified unit stresses, the speaker examined Professor Talbot's bulletins on beams. The 1905 bulletin is devoted to beams reinforced with mild steel bars, and the 1904 series had several tests in which high elastic limit bars were used. The load at the deformation in the steel corresponding to 14 000 lb. and 20 000 lb. was noted, the position of the neutral axis taken from the record equating the total force in compression to the total force in tension, the maximum fiber stress in compression computed, on the basis of a straight line stress strain curve. The value K or $\frac{M}{bd^2}$ was also computed, and a most remarkable agreement was found between these quantities and similar ones as determined from assumptions laid down in the ordinance, especially in the case of the values K. But the load which produced 14 000 lb. was approximately half

TABLE GIVING CO-RELATED STRESSES FROM EXPERIMENTS. 4-17-07

$E_s = 29,000,000$
COMPUTED "C" $= \frac{E_s}{by_1} \times 2$.

K_o = COEFFICIENT AT ULTIMATE MOMENT $M_o = bd^2$

REFERENCE AND BREAKING LOAD	BEAM-DIMENSIONS & KIND OF CONCRETE	% OF REINFORCEMENT	d	M_o	K_o	STEEL DATA: LOAD ÷ λ_s FACTOR	STEEL DATA: $S = \lambda_s \times E_s$	STEEL DATA: q	STEEL DATA: $E_s = q \times \lambda_s \times E_s$	CONCRETE DATA: y_1 FROM EXPERIMENT	CONCRETE DATA: OBSERVED λ_c	CONCRETE DATA: COMPUTED C	"K" FROM ORDINANCE	C FROM ORDINANCE	$M_R = (d-z)E_s$	$K = M_R \div bd^2$
PLAIN ROUND BARS																
TALBOT 1905 11,000 #	# 5 - SPAN - 12'-0" 8" × 11" - d = 10" 1-3-6 CONCRETE LOAD - 1/3 POINTS	.98	10"		330 23 353	5000 ⇒ .00048 2.2	14,000	4 - 1/2" ϕ .184°	11,000	.45d = 4.5"		610	120	660	8.5 93500	117
TALBOT 1905 11,000 #	# 11 - SPAN - 12'-0" 8" × 11" - d = 10" 1-3-6 CONCRETE LOAD - 1/3 POINTS	.98	10"		330 23 353	4500 ⇒ .00048 2.45	14,000	4 1/2" ϕ .184°	11,000	.48d = 4.8		575	120	660	8.4 92500	116
TALBOT 1905 8800 #	# 40 - SPAN - 12'-0" 8" × 11" - d = 10" 1-3-6 CONCRETE LOAD - 1/3 POINTS.	.98	10"		264 23 287	4500 ⇒ 1.96	14,000	4 1/2" ϕ .184°	11,000	.5d = 5"		550	120	660	8.3 91500	114
TALBOT 1905 14400 #	# 33 SPAN - 12'-0" 8" × 11" - d = 10" 1-3-6 CONCRETE LOAD - 1/3 POINTS	1.66	10		432 23 455	8000 ⇒ 1.8	14,000	3 - 3/4" ϕ 1.32°	18,500	.5d = 5"		925	196	930	8.3 154000	192
TALBOT 1905. 12400 #	# 45 SPAN - 12'-0" 8" × 11" - d = 10" 1-3-6 CONCRETE LOAD - 1/3 POINTS	1.84	10"		372 23 395	7800 ⇒ 1.59	14,000	3 - 1/2" ϕ 2 - 3/4" ϕ 1.46°	20,400	.6d = 6"		850	210	1000	8.0 163000	204
TALBOT 1905 15200 #	# 46 SPAN - 12'-0" 8" × 11" - d = 10" 1-3-6 CONCRETE LOAD - 1/3 POINTS.	2.76	10"		456 23 479	10500 ⇒ 1.45	14,000	5 - 3/4" ϕ 2.2°	30,800	.68d = 6.8"		1130			7.8 240000	300
CORRUGATED BARS HIGH ELASTIC LIMIT										$K = .0162\,W + 27$						
TALBOT 1904 20900 #	# 20 SPAN - 14'-0" 12" × 13 1/2" d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS	.70	12"		338 27 365	8800 ⇒ 2.36	20000	5 - 1/2" ◻ 1.0°	20,000	.42d = 5"		667	124	760	10.3 206000	119
TALBOT 1904 20600 #	# 2 SPAN - 14'-0" 12" × 13 1/2" d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS.	.70	12"		335 27 362	8500 2.40	20000	5 - 1/2" ◻ 1.0°	20,000	.4d = 4.8"		692	124	760	10.4 208000	120
TALBOT 1904 29000 #	# 13 SPAN - 14'-0" 12" × 13 1/2" d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS	.97	12"		470 27 497	12800 2.26	20000	7 - 1/2" ◻ 1.4°	28000	.45d = 5.4"		865	168	925	10.2 285000	165
TALBOT 1904 34300 #	# 28 SPAN - 14'-0" 12" × 13 1/2" - d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS	1.52	12"		555 27 582	15400 2.23	20000	6 - 3/4" ◻ @ .565 2.19°	43,800	.52d = 6 1/4"		1170	260	1260	9.9 435000	252
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

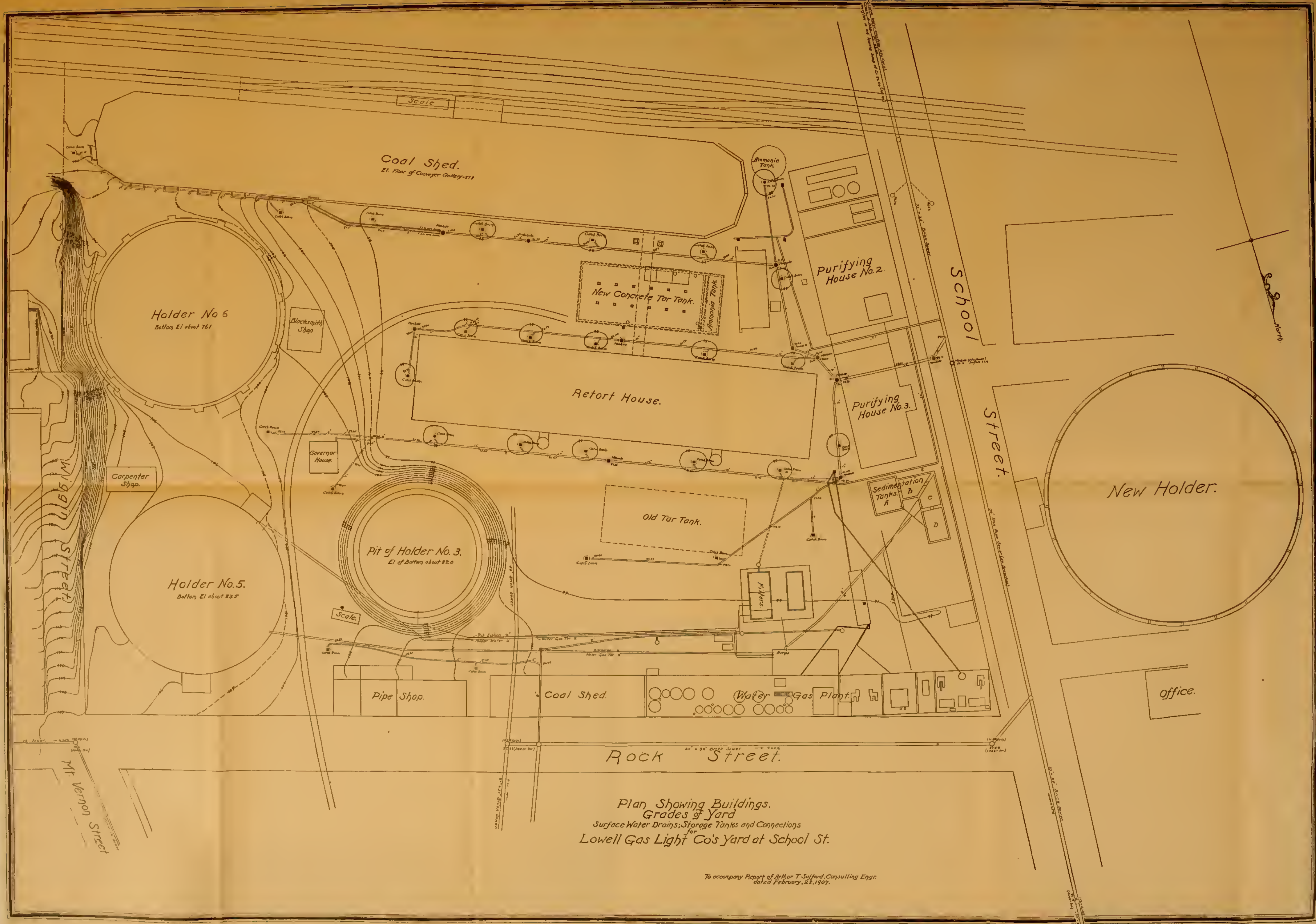
of the ultimate. This, however, is 1: 3: 6 concrete; with 1: 2: 4 concrete it is safe to say that these strength factors would increase until the working factor is about one third of the ultimate. (See Condron's paper before the Western Society of Engineers.)

Referring to table, column 7 gives the total live load on beam when the elongation, as noted, produced 14 000 lb. per square inch in the steel, noted in the next column. In other words, that load is noted which produces 14 000 lb. per square inch in beams reinforced with mild steel, and 20 000 lb. with high elastic limit steel. This load, then, compared with load at which failure took place, and the ratio called factor, is noted in the column with the load. The factor varies from 2.45 with 0.98 per cent. reinforcement to 1.45 at 2.76 per cent. Although it is quite natural that the factor decreases when the beam is over-reinforced, it is interesting to note that even with the 0.98 per cent. reinforcement the factor averaged little over 2. Comparing columns 13, marked "computed C," and 15, "C from ordinance," discloses the fact that the fiber stresses given by assumption in ordinance are higher than those computed from actual observation, which can be explained by the modulus of elasticity in the test specimens differing from the value given in the ordinance. The neutral axis is determined by the ratio of deformation in top and bottom chord, and is, therefore, largely influenced by the ratio of the moduli. The value K, however, is a function of the effective depth and chord stress, and as it can readily be shown, experimentally and analytically, that the variation in the effective depth, that is, the distance from center of tension to center of compression, must necessarily be small, the agreement between values computed from the tests and from specifications of ordinance agree very closely. Compare column 14, "K from ordinance," with last column, 17, "$K = \frac{M_R}{bd^2}$". That the same if not greater factor of safety can be obtained with high elastic limit bars, if bond is such as to prevent slipping until elastic limit is reached when 20 000 lb. per square inch is assumed in the steel, is made evident by the lower section of tests quoted also from Professor Talbot. Indeed, the factor has very little variation, and falls only slightly below 2.25, even for 1.52 per cent. The remarks concerning extreme fiber stress in concrete and factor K apply to this set of tests as well as to the previous one. It would seem, then, that unless there is a serious discrepancy between the actual stress in the reinforcement and the stress as determined by extensometer readings, 14 000 lb. and

20 000 lb. per square inch stress in the steel will mean a factor of safety varying between 2 and 2.5. The ordinance, however, makes these factors much larger by requiring the beams to be figured as non-continuous, but constructed continuous with full reinforcement over support. Also by specifying that slabs shall be designed by the formula $\frac{wl}{12}$. Just how much this increase may be, cannot be determined until enough reliable tests have been made to give true average results. The speaker, however, has tested within the last six months a half dozen full-sized floor panels that were designed on the basis of $\frac{wl}{16}$, and in nearly every case the breaking load exceeded the computed ultimate by 50 per cent. or more. Beams tested at the same time proportioned by the formula $\frac{w}{12}$, exceeded their computed value. The result is that although the stresses may seem high, rules for design increase the factor of safety in all slabs and beams except non-continuous, perhaps even a little beyond the average practice throughout the country.

The many points of excellence about the ordinance are too numerous to take up in detail. It is sufficient to note that its enforcement will bring order out of chaos.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1907, for publication in a subsequent number of the JOURNAL.]



Plan Showing Buildings. Grades of Yard
Surface Water Drains; Storage Tanks and Connections
for
Lowell Gas Light Co's Yard at School St.

To accompany Report of Arthur T. Safford, Consulting Engr. dated February, 23, 1907.

2c
of
m
fig
re
be
m
be
ha
pa
ev
by
po
Th
de
no
th

nu
ent

—

Brc
put

WASTES FROM LOWELL GAS LIGHT COMPANY'S YARD.

By Arthur T. Safford, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, March 6, 1907.]

The following is a paper upon the work done at the Lowell Gas Light Company's yard east of School Street, Lowell, Mass., in connection with the improvements in the drainage of the yard.

The Lowell Gas Light Company has, for more than fifty years, occupied about six acres of land east of School Street, Lowell, and bounded by School, Rock and Wiggin streets and the Boston & Maine Railroad; in addition to this the company, within the last four years, has built a gas holder of 3 000 000 cu. ft. capacity and a new purifying house upon their land west of School Street, but nothing has been necessary so far in the way of drainage on the west side of School Street, and this paper will consider only the old yard.

About two thirds of the old yard east of School Street previous to 1904 was below Elevation 98 on the Locks & Canals datum, which is 15 ft. above the ordinary running mark of the water in the Pawtucket Canal, about 300 ft. away across the Boston & Maine Railroad. The easterly third of this yard was most of it at Elevation 105 on the same datum, but the last 25 ft. is a rocky ledge rising rapidly to Elevation 125.

The low two thirds of the yard just previous to 1904 was occupied by a water gas plant, with a capacity of about 1 000 000 cu. ft. per day, and power plant, at the north side of the yard; a new concrete coal shed 475 ft. long by 70 ft. wide, occupying the south side; a new retort house 287 ft. by 62 ft., occupying the south-central part; a wooden tar tank 102 ft. by 41 ft., the north-central part and two old purifying houses the west side. In addition to these there were numerous small or abandoned buildings in other parts of this end of the yard.

On the area to the east of this were three gas holders, Nos. 3, 5 and 6, of the following size and capacity:

No. 3. 80 ft. in diameter; capacity...... 100 000 cu. ft. (approximate.)
No. 5. 125 ft. in diameter; capacity.................... 500 000 cu. ft.
No. 6. 130 ft. in diameter; capacity.................... 700 000 cu. ft.

In addition to these, and just south of No. 3 holder, there were in the ground the remains of the foundations of No. 4 holder pit which was about the size of No. 3.

I do not know with certainty the original material of the lowest parts of the yard, but it was evidently sand, hard pan and muck, overlying the ledge which was within about 10 ft. of the surface everywhere. All the different holders and foundations for buildings were built upon ledge, which had been blown out and removed at some time from most of the yard. There is every indication that the ledge had been shattered almost up to the base of the rocky hill at Wiggin Street.

The low places in the ground had been filled from time to time, but the material, mostly cinders and dirt, had been disturbed again and again on account of the numerous pipes which had been laid and relaid. The ground was full of blind drains, abandoned pipes of different sizes from 1 in. to 2 ft., and several subterranean springs and tar holes were discovered. In addition to this the old tar tank not only leaked but overflowed after storms and was the one place in the north side of the yard to catch all the drainage from rains or melting snow. From test holes dug in different parts of the yard (north of the new retort house) and elevations taken upon the water, it was estimated that there was at least 1 600 000 gal. of liquid of an objectionable character in the ground excluding what was more or less definitely contained by tanks and holders.

The city sewers around the property include a 30 by 20 in. oval brick sewer in Rock Street, with an average invert elevation of 87.91, connecting with a 30-in. iron pipe sewer with no branches in it, in School Street, to a point about half way down the west side of the yard; this in turn changing at a manhole to a 37 by 25 in. brick sewer, with an invert grade of 86.14 at the manhole opposite the west end of the yard. This sewer crosses the B. & M. Railroad tracks and turns down Western Avenue on the Gas Company's side of the canal, keeping the same size with a slope of 0.25 ft. per 100; continues down Western Avenue through Fletcher Street to Suffolk and through Suffolk towards the Merrimac River at Aiken Street. There is, however, an overflow for storm water into the Pawtucket Canal at School Street, with a crest 4 ft. long at Elevation 88.00, corresponding to the height of water in the sewer at this point when the sewer is about half full. This sewer in School Street takes the place of an older one which ran from Rock Street across the Gas Company's yard to Western Avenue.

The following is a comparison of the low places in the yard with the invert grade of the city sewer at a point where the drainage would naturally go.

	Height on Locks & Canals Datum.	Height Invert City Sewer, Same Datum.	Difference, Feet.
Holder No. 3. Bottom of pit, rough, approximate	89.5	88.38	+1.12
Holder No. 3. Approximate surface of water when full	109.	88.38	+20.62
Holder No. 5. Bottom of pit	83.5	88.38	—4.88
Holder No. 5. Approximate surface of water when full	105.	88.38	+16.62
Holder No. 6. Bottom of pit	76.1	88.38	—12.28
Holder No. 6. Approximate surface of water when full	105.	88.38	+16.62
Coal shed conveyor floor	87.1	86.14	+0.96
Old tar tank bottom, about	88.	86.14	+1.86
Old tar tank surface water, most of time	95.	86.14	+8.86

The pits of these different holders were originally full of water to seal the gas in the holders but had gradually become partially filled up with different liquids produced in the works in addition to the water. The capacity of these pits and the old tar tank is as follows:

No. 3 holder pit	829 100 gal. approximate.
No. 5 holder pit	2 021 500 gal. approximate.
No. 6 holder pit	2 953 900 gal. approximate.
Old tar tank	239 400 gal. approximate.
	6 043 900 gal. approximate.

Nos. 5 and 6 holders contain some objectionable matters which have been held there and the pits have overflowed once or twice, putting some weak ammoniacal liquor down into the lower yard; but the pits do not leak, and as far as I know there is no evidence that they ever contributed to the serious troubles which were the occasion for these changes. They were, therefore, left out of the general plan of improvements. No. 3, however, has had a bad record for many years, and the contents were continually leaking into the ground with a head of 20 ft. or less above the city sewers.

With particular reference to those liquids which required getting rid of: The ground below this holder was full of water

and liquors which filled up the interstices of the soil and loose filling, and, as already mentioned, there were about 1 600 000 gal. of objectionable liquids in the ground here, the 829 100 gal. in No. 3 holder and the 239 400 gal. in the old tar tank, a total of about 2 668 500 gal. to be taken care of. These amounts varied to some extent with the season of the year and the height of the ground water.

In addition to the coal and water gas products stored in the different tanks and ground, there were certain liquids of different sorts produced every day, in amounts which varied with the amount and kind of gas produced. At the time of my first report to the Gas Company, August 22, 1904, they were as follows:

Quantity passing filters, mostly water gas, tar and oil	11 000 to 20 000 gal. per day
Blow-off from gas engine	10 000 gal. per day
Ammoniacal liquor	1 000 gal. per day
Ground water pumped from coal shed	4 000 gal. per day
Coal tar	400 gal. per day
Maximum	35 400 gal. per day

Of this total, the 10 000 gal. per day blown off from the gas engine was not considered because the gas engine was taken out to give place to a steam engine; the ammoniacal liquor and tar could be sold if stored and kept separate from other liquids, and the ground water from the coal shed could be gotten rid of by draining the territory around the shed. There remained, then, this daily quantity of 11 000 to 20 000 gal. of water-gas refuse to be taken care of, besides that remaining in No. 3 holder and the ground.

I have no definite knowledge when the trouble from odors and gases in the city sewers began, but it is an old subject in Lowell, and the new city sewer around the company's yard was built at great expense just previous to the last serious trouble from these wastes. The following extracts from the Lowell *Sun* and *Courier-Citizen*, which are characteristic of a good many such articles appearing about this time, will give some idea of the effects produced and the various criticisms and remedies suggested. I will count on your discounting something from these statements to allow for personal feelings. In some cases statements have been left out of these clippings where personalities have been indulged in.

"JANUARY 14, 1903.

"The public hearing into the cause of gas in the cellars of houses in the vicinity of Suffolk Street was held in the room of the Board of Health yesterday afternoon, and before the board the remonstrants told their experiences with the overpowering odors which, from time to time, fill their houses. Although Mr. O—— was present, he was heard from very little, merely seconding motions on one or two occasions.

"Mr. J—— was the first man to be heard. He said he was an employee of Curley's Market, corner of Adams and Salem streets, and that on several occasions during the past year he had noted the awful odor which had caused so much trouble in the houses in the vicinity. Three or four weeks ago the smell lasted for 48 hr. at a stretch. He had heard many complaints from residents of the section. Not long ago, he said, the Catholic Young Men's League of St. Patrick's parish gave an entertainment and the odor was so strong that it was easily detected in the topmost floor of the building. He thought it was sewer gas and not inflammable.

"Mr. W——, living at 27 Cross Street, has noticed the smell for the past five years. It had, he said, made his mother so sick that she was unable to appear at the hearing being held. He couldn't eat his meals at times, the odor affecting his stomach. He said he didn't dare go into the cellar with a lighted lamp when the gas was the strongest. The tenants of his three-tenement block had moved out from time to time, and those who occupied the block at the present time were unceasing in their complaints. Butter and various other eatables placed in the lower part of the house were spoiled. He claimed the gas came into the cellar under the foundations of the house.

"Mr. R——, who owns eleven tenements on Broadway, represented his father at the hearing, and said that at times the smell was so offensive that it permeated the entire house from cellar to attic. He said that there was no gas piping in any of the houses. He hadn't noticed the odor for three weeks.

"Mrs. L——, 23 Cross Street, said that she, her sister and her daughter had been ill as a result of the gas in her home. She also said that a tenant of the house claimed that the death of an infant child was due to the presence of the fetid gas. She had called on the Board of Health to remove three barrels of apples, vegetables, butter and mincemeat which had spoiled as the result of the gas. Her dog had been found in such a bad condition that she had notified Agent Richardson of the Humane Society to kill it. In describing the effect of the gas on herself she said that it produced nausea, headache and finally vomiting resulted. She had had to sleep on one occasion, when the weather was very cold, without any fire in the house and with all the windows open. Chief Hosmer had visited the place and had not dared to go into the cellar with a lamp.

"Mr. R——, of 3 Salem Street, said his wife and himself had been made very ill from the gas. That was last winter; he

had not noticed it as much this winter. He had been afraid several times that the house would be blown up because it was so full of gas, and he considered it highly inflammable. He had illuminating gas in his house. In the summer months the gas was hardly noticeable; it was when the thermometer lowered that the odors were strongest.

"Mr. C——, of 31 Cross Street, said there was water in his cellar after a heavy rainfall, and that the odors were noticeable after the inflowing of the water.

"Mr. L——, of 27 Cross Street, said that Dr. Johnson had advised him to move from his home if it appeared that there was no remedy for the unhealthful condition of affairs. He thought it was too bad if a man who owned his home should be compelled to move out of it simply because the Gas Company would not attend to its work.

"At the conclusion of the remonstrants' testimony, Agent Knapp said that the stories of the previous persons were not exaggerated in the least.

. . . .

"City Engineer Bowers was then asked to explain the case as he knew it. He said that the Gas Company had run a sewer through their property long before there was a system of sewerage in the city. In 1881 the Locks & Canals Company had prohibited the Gas Company emptying refuse into their canals. Ever since that time, said Mr. Bowers, at times of low barometer and wet weather, people had been troubled with the presence of gas in their cellars. The city had received so many complaints with regard to the matter that the Gas Company had been told that a remedy must be effected. .

"He then told of the large gasometer which had been abandoned by the company but which is full of a residuum which results from the gas-making process. That gasometer was 83 by 21 ft. in size. In the past year nearly around the entire gas plant a city sewer had been constructed, but he said the old Cross Street sewer had been cut off. The end of the trouble was confidently expected then, he said, and for three weeks not a complaint came in, then things began to take on a worse aspect than ever. He had gone to the plant three weeks ago and found everything in a hubbub there.

"'The only thing to do is to dig up the old sewers near the gas works and to build new catch-basins there and to lay new sewers which are perfectly tight. There are some leaks in a few of the pipes. The yard is concreted, and that concrete will have to be dug up. In cutting off the old sewer the yard has been filled with water almost up to the boilers in the engine-room.'

"He said that the soil about the plant was like a sponge, filled with a molasses-like fluid which leaked out of the abandoned tank. The stagnant water around the yard is filled with gas, he said.

"The peculiar part of the whole affair is that although the cause of the gas can be accounted for, it is not within the range

of possibility to say how the odor gets a half a mile from where it emanates and in that half-mile stretch before it is noticeable in Suffolk Street there are many, many houses that have never had one bit of gas in them.

"On a question from Mr. O——, Mr. Bowers said that the gas which had been found in the Massachusetts Mohair Plush Company's works was the same as that which had been detected in Suffolk Street. Many years ago there used to be trouble in Moody Street, but that had not been reported for a long time."

"FEBRUARY 5, 1903.

"The members of the Board of Health, Major Thomas O. Allen, City Engineer Bowers and Superintendent Hintze of the Gas Company, looked over the works of the Lowell Gas Company, in School Street, yesterday afternoon, with relation to the gas nuisance, and to see if a plan for the removal of the disagreeable deposit in the old tank might be hit upon. Nothing definite with regard to a plan was struck and probably will not be until the next meeting of the board, Tuesday afternoon of next week.

"The delegation arrived at the works about 3.30 and was immediately put in care of Superintendent Hintze, who showed the tar substance which is said to be the cause of the odor in the houses in the vicinity of Suffolk Street. It is a tar product. There is a little doubt about it. The olfactory nerves of the members of the board were strained as the different ones took long smells of the samples dished up from an old repository. It was decidedly disagreeable to smell, and one and all agreed that if such an odor permeated the houses of people it must be immediately abated.

"The huge tank, now abandoned, which is said to hold 800 000 gallons of the strong-smelling stuff and water was next visited and walked over. Superintendent Hintze said that the tank which holds the stuff is a little over 21 ft. in depth and 83 ft. in diameter. Nineteen ft. of the depth is largely water, the 2 ft. of deposit on the bottom of the tank is rank-smelling tar product and is forced out into the ground. That the soil about the plant is thoroughly saturated with the syrup-like stuff not anybody will deny.

"The building in which is the tar product will shortly be demolished and the Gas Company officials are in as great a quandary as is the Board of Health.

"The idea of distilling the substance seems temporarily abandoned, although Mr. Hintze said that the company could, without a doubt, make money by distilling it. Aniline colors are present in it; and various tar products, such as musk, asphalt, carbolic acid, etc., could, according to Major Allen, be obtained from it if a process could be determined upon. The stuff is a vegetable decomposition, traced back to its origin from coal. Combined with it are, of course, foreign ingredients which must be eliminated.

"Hundreds of plans have been thought over by those inter-

ested in the matter, and it now seems that the only practicable one is to run the pipe-line. The matter will be threshed over again at the next meeting of the Board of Health."

"MARCH 24, 1903.

"The gas nuisance in Cross Street has been abated as far as Cross Street and Lowell are concerned, but a report from down-river assures us of trouble ahead for the Gas Company from the city of Lawrence.

"The gas nuisance disappeared from the public nostril a week or more ago and for a time no one knew or cared how it had been abated.

"A week or so ago the experts employed by the Pacific Mills began to notice a peculiar stain in some of the goods produced at that mill, according to report, and upon analyzing it found it to be caused by tar.

"An investigation followed, which showed that tar refuse was being carried down the river and was responsible for the trouble, while further investigation showed that in certain places the banks of the river were lined with a mysterious foul-smelling tar deposit."

It was found on investigation that this nuisance was due, not to the discharge of a weak ammoniacal liquor from the upper 12 ft. of No. 3 holder discharged into the canals at Lowell, but to the collection of tar wastes, which had been deposited on the banks of the Merrimac River and carried down stream by the rising river.

During 1903 and the early part of 1904 a good deal of progress in disposing of the daily waste products of the gas houses was made when Mr. Harry W. Clark was called in to advise the Gas Company with reference to filtering the waste products of the water gas, and coke filters were built, which took care of those wastes as long as they were not overcrowded with the contents of No. 3 holder, a part of which was occasionally added by the officials at the works to the regular amount, and the effluent run into the sewers before being properly treated. These filters were 33 ft. long by 15 ft. wide, in three compartments. In the first one the oil and tar were separated out as far as possible and burned and the residue filtered in the other two compartments through 3.5 ft. of coke, the effluent running into a 6-in. tile Akron sewer which discharged into the city sewer in School Street. Twenty thousand gal. per day on these filters would correspond to about 2 000 000 gal. per acre per day through these. This amount was gradually reduced so that, during our work, the amount treated was considerably less than

10 000 gal. per day, and is still less than this now that the Company is making a larger percentage of coal gas.

The most serious part of the trouble from gases and odors during 1903 I now think was due, not so much to the effluent from the wastes produced daily, but to pumping the ground water during the construction of the new retort house built that year directly into the sewers, and if it had not been for this new condition and the overloading of the filters with accumulated wastes from No. 3 holder, the ordinary daily wastes could have been taken care of without difficulty, leaving only the balance of the liquid in No. 3 holder and that in the ground to be gotten rid of.

Sometime after the first of May, 1904, the Lowell Gas Company, after giving me a general outline of the troubles and the remedies suggested, including a large sewer in the bottom of the canal, asked me to examine the conditions at the yard and report upon some plan which could be carried out to remedy the nuisance. I asked Mr. Harry W. Clark to take this matter up with me from the chemical standpoint, and after considering both the engineering and chemical problems, we came to the following conclusions:

The fearful odors in the city sewers, most of them near Suffolk Street and Broadway, were caused by the breaking up of certain coal and water gas tar products and oils which were discharged or found their way into the city sewer in Western Avenue. These waste products appeared to have gotten into the sewers from the Gas Company's yard in a good many ways:

From the old holder pit No. 3 by leakage.

From the surface and ground near the old tar tank.

From the ground at the site of the new retort house during construction.

From the regular daily wastes.

Added to these sources of trouble was the occasional flooding of the yard after storms, adding to that in the ground comparatively clean water, which, getting into the ground, got mixed with the tar wastes there and became unfit to be drained into the sewers without filtration.

It seemed best to us to recommend that the Lowell Gas Light Company begin at once on a definite plan which, when finished, should accomplish the following:

1. Get rid of the contents of the No. 3 holder pit and dry up the bottom.

2. Clean up the ground in all parts of the yard, and provide for keeping it clean.

3. Build a system of tight storm and surface water drains and catch basins to take all clean roof and surface water.

4. Provide tight storage tanks for taking by-products, drips or refuse of any sort.

5. Provide additional filters to remove any objectionable matters produced in the yard so that the effluent would be fit to go into the sewers.

6. Concrete the surface of the yard, so that all roof, surface and snow-water should not get into the ground.

1. *Contents of No. 3 Holder.* — At the time of beginning work, about September 1, 1904, the contents of No. 3 holder had been reduced by leakage and drawing through the filters to 8 ft. in depth, of which the bottom 2 ft. was a black liquid, mostly tar, about the consistency of paint or slush. The upper 6 ft. was a dilute ammoniacal liquor which, as the draft on the coke filters was gradually reduced, was pumped out, filtered and the effluent discharged into the city sewers. The tar in the bottom was mixed with fine coke and burned under the boilers. The pit is now free of all objectionable matters and is used for storing coke.

2. *Cleaning Up the Ground.* — This work was done at two places where the excavation of large amounts of material made it necessary to pump constantly, as well as where digging was done for the drains; and the fact that this work covered three years was a fortunate circumstance for us in a good many ways. The work on the drains covered portions of 1904, 1905 and 1906; the sedimentation tanks were built in 1904 and the new tar tank in 1905. They will be referred to in order of their importance as far as the condition of the ground went.

Old Tar Tank. — The worst place in the yard was the old wooden tar tank occupying the middle of the north side. It not only contained the manufactured coal gas tar which settled to the bottom and was pumped into barrels and sold, but, on top of the tar, about 4 ft. of ammoniacal liquors of various strengths, depending upon the amount of surface and ground water which worked into the tank after storms. The top of this tank was the lowest place in the yard; it was covered with water after a storm; it was unsightly and maintained a pretty nearly constant head on the ground and sewers. It had been such a nuisance that the Gas Company did not wish another tank in the ground, but preferred to build it of steel above the surface. However, as the sedimentation tanks when built were found to be tight, it was decided to build a new covered tar tank of concrete in the

ground south of the retort house, and this was finished in the fall of 1905. The old tank was used through 1904 and 1905, until the completion of the new one, but after the new one was ready to receive the tar and ammoniacal liquors from the works the old one was gradually drawn down, the tar sold and the liquors drawn off and purified through the filters. When it was finally emptied, in 1906, the tank was filled up with good material and the ground graded up. After the frost is out of the ground this spring the surface of the ground above this old tank will, I hope, be concreted and this area will no longer be an eyesore to everybody.

New Tar Tank. — The new tank was built of reinforced concrete 100 by 40 by 10 ft., all inside dimensions, in the yard just south of the retort house. It has one solid partition across the tank, 12 ft. from the west end, with three pipes controlled by gates through it to draw ammoniacal liquor from the main tank into the end compartment at different levels. The material excavated from the site of the new tar tank was composed of ashes, cinders, ledge and the remains of several old walls, retorts and pits. The ground was full of tar, and in one place a subterranean area was discovered connected with pipes which were full of thick coal tar.

The important thing here to look out for was to get all the liquids in the ground within reach pumped out and filtered before they were discharged into the sewers. The following clause was a part of the contract: "The work shall be kept as free as possible from water or other liquids, and all objectionable matters removed before the waste liquids are put into the sewers to the satisfaction of the Lowell Board of Health or the city engineer. The Lowell Gas Light Company will furnish any necessary steam or electric power for pumping or drilling and take the liquids from the new sedimentation tanks to which the contractor will pump them, and provide such other facilities for purifying the liquid as the engineer may think necessary for the proper carrying on of the work up to the time set for completing the contract, and one month in addition if the contract is not completed by September 1, 1905; after that time the contractor shall assume all responsibility for handling and pumping the water or other liquids."

Pumping went on steadily through the progress of this work from the ground into the sedimentation tanks which were built the previous year, and the liquid was filtered before the effluent was discharged into the sewers. No trouble was experienced

from the people living on the line of the sewer excepting at one time when, through carelessness, for one day some water from the site of the tank got into the sewer without being purified. For a short period before the steam pump was put into commission hand-pumping was used and the ground water filtered through some rude filters, simple boxes of coke, into which the liquid was pumped.

The work was let out by contract and, including excavation, rock, pumping, forms and concrete, cost about $16.50 per yard of concrete in place.

The roof of this new tar tank was figured to have coke piled upon it, and now that the top has been covered with tar concrete at the finished grade of the yard it has served its purpose well as a storage tank for tar and ammoniacal liquors without taking away any of the area of the yard, which at present is very necessary. There was no indication of leakage on the inside of the tank when empty, excepting a little moisture, and the liquors in it are securely bottled up.

Sedimentation Tanks. — As already mentioned, I have not taken up these in chronological order, as they were finished before the drains and tar tank; these storage or sedimentation tanks, occupying a portion of the west end of the yard near School Street, were begun during September of 1904 and pushed during that fall to completion as fast as possible in order to provide some means for taking care of the waste products in the ground and the daily wastes if the filters were out of commission. The entire structure is an open L-shaped four-compartment concrete tank with overflows 2 ft. wide and 18 in. below the top; the walls are 48 and 50 ft. on the long sides, 24 and 16 ft. on the short sides and 10 ft. deep below the ground. The capacity was increased somewhat over Mr. Clark's original design on account of the size of the cofferdam and the location of some old holder walls which were found in the excavation. As built the compartments had the following capacities:

A	32 119 gal.
B	17 802 gal.
C	15 708 gal.
D	23 038 gal.
Total	88 667 gal., or

about 9 days' supply, at 10 000 gal. of waste daily.

These tanks were built partly in quicksand and partly over the bottom of old No. 1 holder pit which had been abandoned

for a good many years. The material below the concrete bottom was excavated for a depth of about a foot and refilled with cinders with tile drains leading to a pump hole outside of the tanks. This was kept open for a number of months after the tanks were finished.

The total cost, including excavation, cutting out old walls, rock, building forms and concrete, pumping, etc., was at the rate of about $17.80 per yard. The concrete was not reinforced excepting in one or two places.

During the construction of those tanks the ground was pumped constantly, and all the water from the site of the tanks and for a considerable distance around was pumped clear. It was found that the tanks occupying the site of the old No. 1 holder pit contained a yellowish liquor smelling of ammonia. This was all pumped to the filters and taken care of before going into the sewers. During the next two years these tanks were used to store all wastes, of any sort, which were drawn from the ground or the gas houses excepting what was put into the tar tank.

3. *Drains.* — This work consisted of a general system of tight drains 6 in. to 18 in. in diameter, of deep socket Akron pipe laid with cement joints. They were designed for surface and roof-water only; there was, however, one exception to this rule, a 6-in. drain with open joints on the north side of the upper end of the coal shed. This was put in to intercept clean ground water coming out of the broken ledge at this end of the yard. These drains took the water from the yard by means of tight concrete catch-basins, 4 ft. in diameter and about 6 ft. deep, from 50 to 80 ft. apart, with square iron covers 0.40 ft. below the finished grade of the tar concrete surface of the ground. The drains were figured to discharge as fast as possible the rain falling on one half the roof of the coal shed, the new retort house and the yard. As a basis for this, I divided the yard into seven different areas, which naturally or by grading could discharge over the surface into the proposed drains, and assumed for purposes of calculation that 4 in. of rain might have to be taken care of in 24 hr. and that for a portion of the time it might come at the rate of 2 in. per hour. The sizes were made large enough to carry these amounts without the water being backed up much above the overflows of the catch-basins. It required a possible total of 11.08 cu. ft. per second, or at the rate of 7 164 000 gal. per day during the worst part of the storm. The 10 000 or less gallons a day of manufacturing wastes look very small compared

with this. With the yard full of pipes, and several trials necessary before a straight line could be settled upon, it was not possible to follow out a definite scheme of grades, but the pipes were made a little larger than the scheme called for if the grades were flat, to take off the amounts of water already mentioned. No grade much less than 1 per cent. was used.

The conditions assumed for sizes and grades were made extreme ones because a part of the plan included finally tar concreting the surface of the ground, which, with the roofs, would make the conditions such that the water would get into the sewers and out of the yard as soon as possible after the fall of the rain. These drains were laid at different times during the years of 1904, 1905 and some little cleaning up work during 1906. Any tar or other wastes met with in the ground during the digging for and laying these sewers was pumped to boxes filled with coke, and the tar and oil filtered out and burned, the effluent going into the sewers. The sewers were laid as low as the city sewer in School Street and the overflow into the canal would allow.

The standard prices for this work which were made to cover the three years were as follows:

18 in.	$1.00 per linear ft.
15 in.	0.90 per linear ft.
12 in.	0.80 per linear ft.
10 in.	0.70 per linear ft.
8 in.	0.60 per linear ft.
6 in.	0.50 per linear ft.
Manholes	$32.50 each, complete.
Catch basins	$27.50 each, complete.
Masonry and rock in trenches taken out	$5.00 per yd.

All special and extra work at cost as approved by the engineer, plus 15 per cent.

The extra work due to necessary changes in line in this contract were very large, but the work was well done under great difficulties.

4. *Tight Storage Tanks.* — These included the sedimentation tanks and new tar tank already described in connection with cleaning up the ground.

5. *Additional Filters.* — The original design called for larger filters to be located just north of the sedimentation tanks and to be used in connection with them. It was found, however, after taking care of the wastes during the three years, that the present filters were large enough, until the output of gas increased

Lowell Gas Light Company

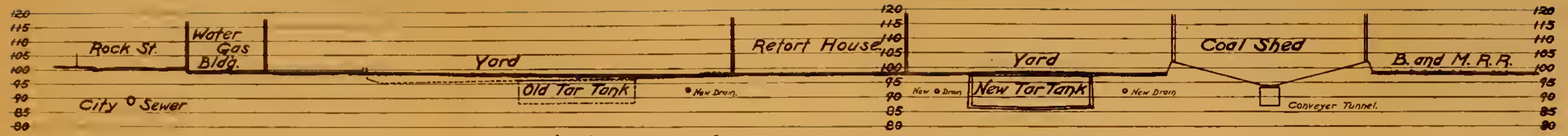
Sections through old Yard East of School Street

Feb. 23, 1907.

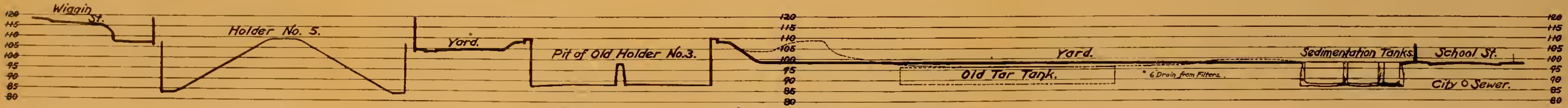
To Accompany Report of Arthur T. Safford

Consulting Engineer

February 28, 1907.



Section North and South from Rock Street to B. and M. R. R. Tracks.



Section East and West from Wiggin Street to School Street.

g

c
g

t
c

f
t
a
present filters were large enough, until the output of gas increased

materially beyond what it now is, and the building of these filters has been put off until they are necessary.

6. *Tar Concreting.* — The final work has been to concrete portions of the yard, particularly around catch-basins, with a 3-in. base of stone and tar and a top dressing of coal tar and sand heated to the proper temperature. The surface of this was laid to an exact grade, the catch-basins being left in a hollow 0.40 ft. deep. This concrete covers now most of the lower yard, including everything south of the retort house and a strip beyond the catch-basins on the north side. After the material filled into the old tar tank has settled properly and the rough grading is ready, this work will be continued until the lower yard will be entirely concreted. The cost of the work was from 70 cents to $1.00 per square yard.

The yard now has been worked over and pumped so thoroughly that it is possible to dig anywhere and, if there is any ground water, find it reasonably clean; the filters, operating for a portion of the week, take care of all the waste liquors except the water-gas tar and oil, which are burned, and the coal-gas tar and ammoniacal liquors, which are sold. The sedimentation tanks are kept for an emergency, with connections to all the different parts of the coal and water-gas plant.

This description covers the work, which has been done since 1904, and which has not only gotten rid of the troubles from gas wastes, but improved the looks of the yard and made the yard room available.

The location of the different structures in the yard east of School Street is shown by the plan used as a working drawing during the construction of the drains, and the elevations of the yard, holder pits, tanks, etc., are shown by two sections, one north and south through the yard, and the other east and west. The old conditions are shown by dotted lines, the new or finished grades by full lines.

Since the completion of the work and writing the first draft of this paper I have taken the time to look up all the references to troubles due to gas wastes abroad and elsewhere in this country which were given in the gas journals of Great Britain and the United States. There are very few such references, and the causes of the troubles and the remedies are mostly local in their application, as in the case of the Lowell Company. I have found no evidences of tarry matters having been actually separated out and discharged into sewers, but dilute ammoniacal liquor and

waste products containing small amounts of tar and oil have been. There are probably two reasons for the few published records of trouble,—the common idea that anything can be put into sewers, and the unwillingness on the part of gas companies to acknowledge that the bad conditions are produced by the wastes from their works. Most of the common objections to gas works are on account of smells, noise or smoke; these offend the senses but do not often do more than this. Smells which may be offensive to some are not noticed by others, and children of the present generation in Lowell have been taken to the gas works and held over the tar tanks when troubled with colds of a croupy nature.

Among the different published reports there are two which have more than a local interest, and at the risk of making this paper too long I have included portions of them, as they represent similar conditions elsewhere.

The first is an article by John Radcliffe with regard to certain troubles from ammoniacal liquor and its waste products from the gas works at Sutton (Surrey), England, and their treatment. It is published in the English *Journal of Gas Lighting, Water Supply, etc.*, in the number of October 2, 1906. It is of special interest on account of the effect upon the Sutton sewage beds and the reference to Mr. Dibdin.

* "Gas, coke-oven and chemical works which make large volumes of this waste product now find it difficult to dispose of without trouble ensuing with one or other of the various authorities with whom they may come into conflict, and those works are exceptionally situated which find themselves able to safely select one of the several means available.

"When the works were fewer in number and the temperatures of distillation were not high in degree, no doubt the liquor was discharged and eventually entered the natural channels, which are water courses, without unduly depreciating their value for any purpose, but with the development of the industries and the attainment of high retort temperatures, the accumulation of injurious substances, more particularly phenolic bodies and compounds of cyanogen, can be so great that the river boards, fisheries commissions and sanitary and water-supply authorities have been obliged to call attention to the damage and injury which may be done. In a large number of instances prohibition of discharge from works has been issued. There are works which have found it necessary to cease the distillation of ammonia, shut down the plant and sell the liquor for whatever it will bring them. And there are indications leading to the conclusion that the river boards in different parts of the country will no longer

* "The Difficulties of Disposing of Ammonia-Spent Liquor, and Certain Results of Its Purification." By John Radcliffe.

permit the discharge of the spent-liquor into watercourses indirectly or directly. Works placed on the coast as a rule have nothing to fear, but others on estuaries which are fishing grounds have had to avoid discharging the crude effluent to the sea.

"Some works situated inland allow it to percolate the earth, and where the underlying strata are deep and porous the method is a safe one. But if shallow, that is to say, if the effluent cannot sink below the level of streams adjacent, it is bound eventually to appear in them. Fortunately or unfortunately, the analytical test for the most objectionable of its constituents is extremely sensitive and unmistakable, so that the presence of spent-liquor can be ascertained with certainty and its proportion inferred.

"Other works are obliged to have recourse to very expensive evaporation until solid residue is obtained which is carried away. Sometimes a portion of the evaporation is done in boilers for steam raising, to the damage of the fittings, and is a mere postponement of the trouble. There are coke-oven plants using again for gas-washing the liquor from which the free ammonia only has been removed, and the cycle of operations is continued until the ammonia-liquor is saturated with fixed ammonium salts. It is then decomposed with lime and a concentrated spent-liquor obtained. This is evaporated and the solid residue is carried away as in the previous instance. But these residues still contain all the objectionable impurities of the original liquor. If the mass is buried, being deliquescent, it soon becomes fluid and drains away unless confined in water-tight pits. If thrown on to the land, it must be percolated through the earth by rain and washed into watercourses eventually, and then the distiller arrives at exactly the same end (after spending a lot of money) as if he had pumped the spent-liquor on to the land or run it into a stream.

"There is much difference of opinion as to what is the effect of spent-liquor upon sewage treatment when passed into the works' drains, and as in most cases this method of disposal will be the readiest and most convenient, it is necessary to more closely consider it.

"If the subsequent treatment of sewage consists in the removal of solid matter by lime and materials of a similar character, the cyanogen compounds will remain in solution, and the prohibition of the River Boards against discharge may be applied. If the treatment consists in pumping the sewage upon land to be afterwards cultivated, the spent-liquor in some instances has not been found to hinder vegetable growth, but in most cases has been found to seriously interfere with it. The result will depend upon the proportion present and its composition. Usually the proportion of the spent-liquor will be under 1 per cent., and should it hold about this amount, and the liquor contain under the equivalent of 0.15 per cent. of ammonium sulphocyanide and be free from tar particles, with the phenolic compounds low in amount and be not immoderately alkaline, the probability is that

cultivation will not be interfered with and the bacteria of the soil and the sewage will be able to decompose the salts of the liquor. If, however, the water supply is only a small one and the proportion of liquor increased, or, as is usually the case, has a larger amount of injurious compounds present than that indicated, vegetable growth will be retarded, or even prevented, the sewage matter will not be quickly absorbed and the salts of the liquor will remain longer undecomposed, with the serious consequences of both remaining a dangerous period of time on the land with all the accompanying risks.

"If the system of treatment is the modern one of septic tanks the same remarks apply as in the previous instance, and each case must be considered in relation to all the circumstances of it. The consequences will be dependent upon the proportion of spent-liquor, its composition and the degree of aëration arrived at in the beds. It is obvious this must be the case. There are exceptional instances of works which have passed their liquor to bacteria beds without damage to them being reported, but statements have been made in general terms that this material is not injurious. The experiences of the Sutton (Surrey) Gas Company may be cited to show otherwise. The double-contact bacterial beds for the treatment of sewage were first devised by Mr. Dibdin, who originated the system, and the first beds in this or in any country were put down at Sutton twenty years ago and have been a model for all others. Public bodies from all parts of the world have visited and copied them. The engineer at the time of the inception was Mr. Chambers Smith who, during the whole time up to the present, has had the system under his charge on behalf of the district council.

"The Sutton Gas Company up to March, 1905, sold their ammoniacal liquor. In April they had built a sulphate-house, put down a new sulphate plant of the most modern type (the devil liquor being redistilled) and began to work it. The spent liquor was passed to the sewers. Compared with some others it may be said to be a rather harmless liquor, containing the equivalent of 0.15 per cent. of ammonium sulphocyanide and a proportionate amount of other impurities. The volume added was 3 per cent. Soon after the plant started it was reported that the quality of the sewage-effluent had become deteriorated. Reports are regularly made. In a few days the sewage-effluent had a foul smell and the beds became completely ineffective. The medical officer of health (Dr. Bower) examined them and found that most of the bacteria were killed and those that were not dead were undeveloped, enfeebled visibly and ineffective. The sulphate plant worked for three weeks and then stopped, and the trouble at the sewage beds thereupon vanished. The gas works went back to their practice of selling ammoniacal liquor and the trouble at the beds did not recur. It appeared that the company were not correctly informed of the volume of sewage with which the liquor would be mixed. The experience of the Waltham Abbey Gas Company is precisely the same. The sul-

phate plant was stopped nearly two years on account of the same difficulty. It seems in many cases that, if ammonia plants are to work at all, a process of liquor purification is essential.

"In August, 1905, the Sutton Gas Company, who were standing to lose a lot of money, instructed the writer to put down a purification plant, which began to work in September. It fulfilled the requirements in being inexpensive and simple, and resulted in the continuous and automatic removal of free lime, tar particles, organic ammonia, sulphocyanides, cyanides, ferrocyanides and sulphides, and also compounds of dithiocyanogen, which the writer has observed in many samples of spent liquor. Samples of the purified effluent were submitted by the council to Dr. Bower, who reported: 'To various proportions of crude sewage from the farm were added 1 per cent., 5 per cent. and 25 per cent. of the purified effluent from the sulphate of ammonia plant, and cultivation experiments made. I found that bacterial growth was not appreciably inhibited by any less quantity than 25 per cent. of the effluent.' The Clinical Research Association also reported to Dr. Bower as follows: 'A 1 per cent. dilution is without action on the colon bacillus, which, in fact, grows freely in nutriment broth containing this amount of fluid.' The Gas Company sent samples to Dr. Otto Hehner, who reported:

" 'I procured some sewage effluent from the Metropolitan Northern Outfall Works at Beckton, and added to measured quantities of it (after straining out the coarser particles by filtration through cotton wool) various proportions of the (purified) ammonia plant effluent. These mixtures I kept at about 23 degrees cent. (a little below blood heat) for some 5 hours, so as to give to the chemicals contained in the liquor a due chance of injuriously affecting the bacteria. I at the same time incubated a sample of the sewage without addition of effluent. From each incubated sample I then prepared dilutions from which I cultivated gelatine plates and agar plates, the former at ordinary temperature, the latter at blood heat. The number of colonies that had developed was ascertained, and the results are stated in the following table, in which due allowance is made for the dilution of the sewage by the addition of the purified gas effluent.

GELATINE CULTURES.

	Total No. of Bacteria per Cu. Cm. of Sewage.
Sewage without addition	2 419 000
Sewage plus 4 per cent. of purified effluent	2 337 000
Sewage plus 6 per cent. of purified effluent	2 475 000
Sewage plus 8 per cent. of purified effluent	3 211 000
Sewage plus 12 per cent. of purified effluent	3 846 000
Sewage plus 16 per cent. of purified effluent	3 717 000

AGAR CULTURES AT BLOOD HEAT.

Sewage without addition	1 058 000
Sewage plus 4 per cent. of purified effluent	1 576 000
Sewage plus 6 per cent. of purified effluent	1 800 000
Sewage plus 8 per cent. of purified effluent	1 844 000
Sewage plus 12 per cent. of purified effluent	2 933 000
Sewage plus 16 per cent. of purified effluent	1 753 000

" 'It is abundantly clear from the above results that this effluent, when added to sewage in proportions up to 12 per cent., has not only not antiseptic bactericidal action, but greatly stimulates their growth and development, almost twice as many bacteria developing in gelatine and three times as many with agar at blood heat in the presence of 12 per cent. of liquor than in sewage alone. It is clear that the liquor furnishes some food materials to bacterial life.

" 'When the proportion of effluent exceeds 12 per cent. a slight inhibitive effect begins to appear, but even with 16 per cent. the bacterial development is considerably greater than in pure sewage. The discharge of purified effluent of the nature of the sample upon which I experimented into the Sutton sewers therefore assists the proper working of the bacteria beds in which the sewage is treated, and is without the least injurious influence.'

" This conclusion was placed before Mr. Dibdin, who stated that when sufficient of the poisonous substances was removed the bacteria would be able to decompose and feed upon the remaining salts.

" Upon the strength of these reports the Gas Company, who had in the meantime been using the purified effluent for works purposes, passed it into the drains in the same proportion as before, viz., 3 per cent., and the results have justified expectations. It has been going to the beds right up to the present time, and Mr. Chambers Smith has stated there are no complaints to make. The sulphate plant works three weeks and stops two, and an observer who regularly sees the sewage effluent vouches that when the purified liquor is passing to the beds the quality of the sewage effluent is improved. As the proportion added will always be under 3 per cent., and in most cases 1 per cent., the effectiveness of the treatment is apparent, as 25 per cent. can be safely added. A similar purification plant is now working at Waltham Abbey and the results are equally good. The Corporation of Coventry are adopting the process for their new works at Foleshill and other works also.

" I think it can now be stated that ammonia-spent liquor in some instances injures bacteria beds, and further that it is possible to purify it with the result of its being beneficial. Purification, indeed, affords the simplest solution of the problem."

This article quoted is valuable not only for its contribution to the general knowledge of the subject, but for its promised remedies for the bad effect of gas waste liquors on those communities where sewage disposal, other than the discharge of crude sewage into streams, is necessary. I only wish I could report from personal knowledge of the good results which have apparently been obtained at Sutton, England.

With reference to published reports of troubles from gas refuse in this country, I have included extracts from a very interesting paper by Frederick H. Shilton, of Philadelphia, Pa.,

who built a gas plant near a discriminating neighborhood and ar nged for the disposal of the wastes with the idea of reducing t a minimum the nuisances of all kinds. This paper is published in the *American Gas Light Journal*, March, 1899, page 337. My notes were made under difficult circumstances and there may be some errors in the extracts. He says that " a gas company must conduct its business and operate its plant in such a way as will not injure its neighbors." He defines a nuisance as " that which offends an ordinary man but not a delicate-nosed one." The following have been ruled as nuisances: " Pollution of private wells adjacent; the pollution of state streams; pollution of rivers used for water supply; emission of noxious fumes destroying vegetation; emission of smoke, cinders or odor, steam and other noxious vapors; grit of heavy machinery."

According to Mr. Shilton, smell comes from various causes:

" 1. Leaky oil tanks.
" 2. Saturated earth from oil drips.
" 3. Drip water not properly disposed of.
" 4. Foul water by blowing of holders.
" 5. Escaping gas from purging water gas refuse.
" 6. Escaping gas from opening purifiers.
" 7. Vapor from spent lime or foul oxide.
" 8. Tar wells.
" 9. Tarry sawdust or breeze from purifiers."

Offensive drainage may come from

" 1. Unintercepted scrubber or condenser water saturated or laden with ammonia tar or oily scum.
" 2. Tar or oil wasted.
" 3. Rain washings of spent lime or old oxide.
" 4. General gas works and surface drainage.
" 5. Drip water not properly disposed of."

In the design of this particular plant the following provisions were made for offensive refuse and drainage:

" All water used in scrubbing, and all water that comes from the various seal pots, overflows, etc., containing whatever tar or oily refuse matter is made in the process of manufacture, is led to tar separators already mentioned. These are rectangular, well-made wooden tanks or vats buried in the earth, saving removable plank closely fitted tops. They are so designed with proper partitions, baffling boards, compartments, etc., that the water flowing in them passes through but slowly, and in this passage the tar is intercepted and precipitated to the bottom to be afterwards pumped out into barrels and sold or otherwise disposed of. If any free oil appears on the surface it will be

caught and skimmed off and returned to the oil tank. The water after being cleaned as above is then pumped back by a circulating pump and used over and over again through the scrubbers and seal pots as before. The result is that no considerable quantity is constantly flowing off or consumed, but a small amount, say 3 or 4 gal. per 1 000, needs to be taken care of. This is so clean that it is allowed to go into a small creek in the rear of the works, as no pollution ensues. An ordinary cesspool takes care of the office and closet drainage."

The general conclusions which can be drawn from a study of this problem, and the results of the work at Lowell, Mass., and elsewhere, are as follows:

The ordinary wastes of a coal and water gas plant can be taken care of within the works by separating and burning the heavier matters and treating chemically or filtering through coke the lighter liquids, and the effluent will not cause trouble in the public sewers, but this effluent should be treated specially if the sewage is disposed of on land.

Storage tanks for several days' waste, which are perfectly tight, should be provided against breakdowns in the collection of waste products, and should be divided into compartments, with overflows, in order to separate the wastes whenever necessary.

If the ground within the yard is porous and there are old wastes of an objectionable nature which have accumulated, these should be filtered through coke before being discharged, and for the best results a separate system of storm water drains should be provided to include roof water as well as surface water; if it is necessary to keep the ground entirely clean the yard may be concreted.

I wish here to express my obligations to Mr. Arthur C. Pease, the former superintendent of the works, who died of pneumonia about the middle of January. He was not only of great help to Mr. Clark and myself in working out these different problems, but designed and put into operation the scheme for burning the oil and tar from the water-gas plant by spraying them under the boilers. He had agreed to speak for the manufacturing side before the Society at this time, and this discussion will not be as complete as I hoped it would be.

DISCUSSION.

Mr. H. W. Clark. — Mr. Safford has told you nearly the entire story in regard to cleaning up the Lowell gas nuisance and

the methods followed to get rid of the objectionable waste liquors in the old holders and in the ground. When I was first called into this case by the president of the Lowell Gas Company it was presented to me as a very small problem compared with what it developed into later. The bad repute into which the plant had fallen among those living in the neighborhood or connected with the same sewer was stated to be due entirely to the waste products from the water-gas plant, and I was at first asked to study only the wastes from this plant. I found that water gas made in the usual way had the usual tarry and oily waste liquid. In making water gas, the wastes from the gas machines collect in and pass through what are known as seal pots and consist of water, light and heavy oils, tar and tarry matter. The amount of this liquor produced per million cubic feet of gas made per day varies, but in such plants as I have had opportunity to examine is about 12 000 gal. per million feet of gas. From these seal pots or water seals at the Lowell plant the water oils and tarry matters flow into what is known as the tar settling tank or separator. A certain separation of tar, water and oil occurs here, and from this tank the water is continually pumped back into the water seals. Into this tank a certain amount of condenser water is also collected. There had been installed at that time by the gas company, to treat the waste liquors accumulating in this tar-settling tank, a plant designed by a certain sewage disposal company, so called. This plant consisted of two small concrete settling basins about 6 by 3 ft. and 2.5 ft. deep, a third settling basin of about the same size to which the liquid went after passage through the first basins and coke strainers about a square foot in size and a few inches thick. Near these tanks were two sets of filter beds with a total area of 400 sq. ft., the material of these beds being a mixture of sand and coke breeze and the depth of the beds about 3.5 ft. To these the liquid was passed after the preliminary treatment. The plant was guaranteed by the sewage company, so I was told, to care for 5 000 gal. of waste daily. One sample only of the effluent of this plant had been collected by the filter company, so I was told by the superintendent of the gas works, and that on the first day of its operation. It is needless to say that it was "clear and colorless," as all such samples collected for a special purpose are always stated to be. I believe it was not claimed to be odorless. After running about a week these filters became badly clogged with tarry matters, and consequently when I first saw them they had been out of use most of the time since their con-

struction. The effluent passing from them had the strong, penetrating and disagreeable odor objected to by the surrounding community. At the time I was consulted there were 10 000 to 12 000 gal. of this liquor to be disposed of each day. It was evident, of course, from the composition of this waste liquid, that its treatment was not a question of purification by filtration, that is, by bacterial filtration, but rather one of precipitation and straining. I found after making a few experiments that lime was the cheapest and most efficient precipitant to use, and that by its use a good precipitation could be obtained with 3 000 to 4 000 lb. per million gallons, or in actual amounts 30 or 40 lb. per each day's production of waste liquor at the Lowell gas plant. Adding a lime tank, introducing milk of lime to the waste after it had passed through a preliminary settling tank and increasing the size of the coke strainers resulted in good precipitation and oil removal and the production of a fairly clear, yellowish or brownish liquor with its suspended matters removed by the precipitant, most of its oil caught by the coke and the liquid much reduced in odor. The application of this to the filters has given an end liquor that is fairly clear and certainly free enough from odor to be run into a city sewer, and that was the only requirement at Lowell. The tar collected in the tar tank and that in the sedimentation tank is pumped out from time to time, mixed with coke and used for fuel at the gas plant. As I have said, this was the only part of the works that I was at first asked to improve, if possible, and not until considerably later did the Gas Company conclude that the whole problem, ground water, leakage from abandoned holders, etc., must be studied in a broader way. Mr. Safford has told the results of this later work. Since the Lowell work I have had occasion to study similar gas liquor problems at other places. At Paterson, N. J., I found that the water-gas waste was one of the chief industrial wastes aiding in the pollution of the Passaic River, although they had quite an elaborate system of so-called separator tanks with baffles arranged to hold back the tar and prevent the passage of light oils upon the surface of the liquid. At the Paterson works about 2 500 000 ft. of water gas were made daily, from 10 000 to 12 000 gal. of Texas gas oil used daily and about 40 000 gal. of waste liquor passed into the river each day; also about 1 500 to 2 000 gal. of tar retained each day and burned under the boilers, one boiler being built to burn tar only, and two others tar that was sprayed or shot in on to the coal, as Mr. Safford has mentioned is now done at Lowell.

Mr. William E. McKay. — I have been greatly interested in Mr. Safford's paper. A number of years ago, at a gas works of which I was the engineer, the surplus tarry water from the manufacture of water gas had been allowed to flow into the adjacent salt-water bay. The small percentage of oily tar contained in the overflow water spread over the flats and emitted an unpleasant odor. At high tides this oily scum discolored the paint on the yachts sailing over the bay. To remove cause for complaint we provided a system for the repeated use of the same water in the manufacture of water gas; we installed a system of separating and settling tanks and a coke filter.

As a consequence of these changes the volume of water running to waste was reduced to 2 gallons per thousand cubic feet of gas made, and this waste water was entirely freed from tar or oil.

In the case of a gas works in Connecticut, where I was employed as consulting engineer, the plant was situated on the banks of a small river. In this case the tar from the manufacture of oil gas had been allowed to run into the river and this had resulted in many complaints and in several damage suits.

In this instance also we put in a system of separating the tar from the water by heating the liquid, and the waste water was finally filtered so that it was quite clean when it ran into the river. All cause for complaint was entirely removed.

In the case of the Boston Consolidated Gas Company, oil storage tanks are placed within concrete tanks and thus double provision is made against trouble from leaks. The proper disposition of drip water is to treat it as above described for tar water.

By providing a two-level overflow from gas-holder tanks it is possible to prevent the loss of oily water from an accidental blowing of the gas-holder.

In the matter of ammoniacal liquor, whether the solution is strong or weak, the waste of this liquor is a loss to the gas company, as ammonia is a valuable by-product, and except in the case of the very smallest gas companies no portion of the ammonia liquor should be allowed to run to waste either purposely or accidentally. At one of our stations we have recently built a storage tank for ammonia liquor 50 ft. in diameter by 21 ft. in height. This tank is built of reinforced concrete, and the floor and roof are reinforced concrete; when completed the entire interior of the tank was thoroughly coated with thick tar or thin pitch applied hot. This tank has been in use over a year and has

proved absolutely tight. The construction of ammonia storage tanks offers some difficulty because ammonia vapors rapidly corrode steel and iron. On the other hand, several expanded metal tanks built for the storage of ammonia liquor had not proved wholly satisfactory; we are disposed to believe that the waterproofing of the concrete with thin pitch is an element in this tank construction that has insured its success.

Mr. George Bowers. — You can imagine what my life was for five or ten years before Mr. Safford started on this problem. He has given you an intimation of the trouble in the newspaper clippings which he has read. The question was whether the Gas Company could be prevented from using the sewers or not. If we shut them off they would stop the gas business in Lowell and, of course, that would make trouble that we could not control, so we did not do it. I have a map of that part of the city which I will present to you as a diagram of this matter. This smell which is talked about, you would call a smell of gas; it has an odor like it, but it is not gas at all. It is what is called ammoniacal liquor, and people who have had it in their houses say it makes them sick. You wouldn't think much of it until you happened to get a whiff of it yourself. If you stood over a manhole when that odor came up everything inside you would come up as quick as lightning; you wouldn't have any time to think of it. Our superintendent of streets did not believe in this trouble until he stood over one of those manholes; then he went out of sight very quickly and had nothing more to say.

The Lowell Gas Light Company is situated at the corner of School Street and Western Avenue. All the drainage pipes from their works enter the sewer in School Street, which runs down School Street to Western Avenue, thence through Fletcher and Suffolk streets to Cross Street, a distance of about 4 000 ft., where the first trouble is located. Here are two or three houses where the people have been greatly troubled with this odor. From Cross Street the sewer continues down Suffolk Street to Moody Street, thence to Cabot Street, a distance of 2 000 ft. more, where we have the same trouble.

The Cross Street sewer is an 18-in. pipe sewer and falls about 3 ft. into the sewer in Suffolk Street. About 300 ft. from here our worst trouble is experienced. I have been called many times to the Lyons house, and have found the people at this place greatly agitated over the odor. The sewer connection here seems to be good; there is an iron trap in the cellar, and if you take the cover from the trap you will not get any gas smell

from it. There are houses connected with the sewer all the way from the gas works to this place, and the question is, Why does the trouble break out in these particular spots, so far removed from the gas works? None of these houses are located on the main sewers, but all are on branch sewers emptying into main sewers.

Mr. Weston. — There could not be a leak in it?

Mr. Bowers. — It would seem so, but how does the odor get there?

Mr. Weston. — Don't you get it from all the manholes all along?

Mr. Bowers. — You get it like this. It will come out here and there, and will skip a lot of them before it comes out. You will not find it right along; it will be in spots.

Mr. Farnham. — Do these houses stand any higher than the houses around them?

Mr. Bowers. — No. All along the street they are just the same. This particular house has it all the time. They get it first, and when it is bad it will go to the houses further along; and when it is very bad you get it in the street itself. It will come out of the manholes and people have to close their windows.

Mr. Farnham. — Do all of the houses in Lowell have a running trap for their connection?

Mr. Bowers. — Yes.

Mr. Adams. — What is the grade of the sewer directly below this Lyons house? I see it is on a branch sewer and not on the main.

Mr. Bowers. — About one in a hundred, and it has a fall of 3 ft. into the big sewer about 200 ft. from the Lyons house. It has manholes with large openings in the covers, and there is one about 100 ft. from the Lyons house, so that all gases should come out into the street before reaching this house. There is no reason why it should stay in the sewer until it came to the house. The Gas Company have scraped the snow and ice from the covers and kept them clean all the time, so that the gas should come out into the street and not be forced into the house.

Mr. Adams. — What is the foundation?

Mr. Bowers. — Ledge.

Mr. Adams. — It isn't in the ledge?

Mr. Bowers. — I don't think so.

Mr. Winslow. — Has this trouble occurred at any season of the year particularly?

Mr. Bowers. — It is worse when we have dull, heavy

weather; generally in the fall or in the spring when the snow is going off we have a good deal of trouble. When the concrete is washed in the gas-works yard you will find a little trace of oil in the sewer. Officials of the Gas Company deny that they allow any of this oil to enter the sewer. I have sometimes thought that it was due to the hot water which enters the sewer at several places. There are several large manufactories with steam plants, and they blow off their boilers into tanks and run a great deal of hot water into the sewers, which makes them look greasy and oily.

Mr. Barnum. — Mr. President, the gas companies in past years have let a good many liquids go into the sewer on which they could afford to spend a good deal of money in saving, which would bring them in a large return. One of these is the ammoniacal liquor. That is very easily retained by simply washing the gas with cold water, and letting all the liquor and the tar go into settling tanks, pumping off the liquor and the tar; there would be some water of condensation beyond the point where the ammonia is taken out, which would come on the top of a settling tank and that can go into the sewer and is perfectly good, provided the gas is properly cleaned before it reaches that point.

The waste from coal gas can be taken care of by engineering principles, simply by the expenditure of a reasonable amount of money for settling tanks. The trouble has come with sewers since water gas has been introduced. That is made from a crude oil, and the amount of oil and the proportion of oil and water and tar in the waste depend upon the character of oil and the temperature at which the gas is made. The tar being heavier than water, if the whole amount of waste is allowed to stand in settling tanks, the tar settles to the bottom and can be pumped off, and is worth about 4 cents a gallon as fuel. Where the trouble comes is in the oil; that has a most disagreeable odor, and is the odor that the gentleman from Lowell describes, and is a very difficult thing to remove, but it will yield to treatment such as Mr. Clark described.

The tar settles nicely and can be pumped, and as I say, the trouble comes in getting the oil off the top; that is what gives the very disagreeable odor, especially as the waste comes from the water gas at a temperature of 160 degrees and has to be cooled down. Then if any of this gets into the sewer and it should meet with any hot water or exhaust steam the trouble is more than abundant.

As for the place where the odor was noticed, I have had similar experience and found that there was some exhaust steam somewhere near that was heating it up; some local condition made it appear here or there, but the fundamental reason was that it was getting heated near that point somewhere.

The tanks that we have in Worcester to care for the coal gas are abundant and there is no trouble from that. For the water gas we put in a new system for separating and filtering. The liquor passes through eight tanks, 6 by 6 by 6, with large passageways between so as not to disturb and carry the settled tar along with it, and the liquid goes down from one tank underneath the baffle plate which extends within 18 in. of the bottom, and then up and over the next partition and through eight of these sections, 6 by 6 by 6 ft.

I have some samples here that I will show you. It is not stirred up now, but it is similar to what Mr. Safford showed you; what causes the trouble is the oil on the top. Here is the liquid that goes into the inlet of the settling tank. The liquid that comes out of the outlet of these eight tanks, which is the outlet of the settling tanks, comes like this. Now you will see that that has quite a little oil on top. The settling tanks will take out all but the oil on the top, and the coke will take out the oil, although a slight color will be left to the effluent due to the coke. Some color or film will come from perfectly clean coke.

The Chairman.— Is that coke replenished from time to time?

Mr. Barnum. — That coke is replaced in the summer time about once a month and in the winter time about once a week, and being soaked with oil we take it to the boiler house and burn it. It makes a very cheap material for filtering.

These tanks are adaptable; they are quite flexible; you can increase their capacity. We have drain pipes from the settling tanks where the tar can be pumped off every day. The drain pipes in the coke basins also increase the capacity. I have run them as high as 150 gal. per minute. That sample was taken off at the rate of about 75 gal. I think, Mr. President, that is all I can say in regard to it. I would be very glad to answer any questions.

Mr. Bowers. — This business at Worcester is all done by the Worcester Gas Light Company, is it?

Mr. Barnum. — Yes. That is all done by the Gas Company. We built the tanks.

Mr. Bowers. — Did you have trouble there with the citizens making complaints?

Mr. Barnum. — Yes. Before we put in the new system our old tanks were made of wood and they leaked from section to section without following the proper course through, and they weren't large enough; when our make of gas was very large, that water would go in, looking very much like that second bottle, or even the third, and that would get into the sewer; there was a brewery across the way and the hot water from that brewery would get into the sewer and come in contact with this effluent, and when we had a south wind up through the valley that would take the odor up to the top of the hill about a quarter of a mile from the works, and then we would have complaints, and they were quite numerous.

Mr. Eddy.— There is one interesting thing in this connection which Mr. Barnum has not spoken of. It happens sometimes that the odors from the gas wastes are noticed by the citizens and something is causing the trouble which must continue.

For instance, in cleaning out the large surface water drain some time ago, which was a matter of a week or two, people would continue to get the odors throughout the time. I found by putting a curtain in the sewer on a wooden frame, made of cotton cloth or very light duck, it stopped the passage of the air current up the sewers, and furnished practical relief for several days. That may get you out of a scrape some time if you get into it.

Mr. Bowers. — Are the sewers and the manholes covered with oil?

Mr. Eddy. — Sometimes it is very thick, so thick that a man could not get into the sewer without getting covered with it. We have been cleaning out the sewers at the north end of the city above the gas works but below a local mill gas plant recently, and there the tar was up in the manhole to a good height where the water had carried it during high water, and not only was it on the sides of the manhole and on the sides of the sewer, but it had cemented the sand in the bottom of it; it had settled to the bottom of the sewer and made a thick paste of it, so it was very hard to clean out.

[Note.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1907, for publication in a subsequent number of the Journal.]

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIX. OCTOBER, 1907. NO. 4.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

STATE PROTECTION OF THE PURITY OF INLAND WATERS.

BY R. WINTHROP PRATT, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Civil Engineers' Club of Cleveland, April 9, 1907.]

LAWS protecting the individual rights of riparian owners have been in force ever since the time of the Romans, and perhaps before that time. These laws are founded on the general principle that water, like air, is the common property of mankind, and that water flowing over the land is part of the realty and belongs to a certain extent to the owner of the soil. Such owner may take part of it for his own use, and may thus incidentally diminish its volume and perhaps alter its quality. But as the water naturally passes on to the owner of the adjoining soil, the next owner has precisely the same rights. It follows then, according to the above principle, that no riparian owner may appropriate all the water which comes to him, nor pollute, nor injure it so that the rights of other owners may be interfered with. In the past, the conflicting rights of different riparian owners have caused litigation in hundreds of instances.

It is impossible to define by law the exact extent to which the several riparian owners may use a stream. Generally speaking, however, the courts have decided that each one may make such use of the water for farming and domestic purposes as is reasonable, and the lower owners must expect the slight decrease in quantity and change in quality which necessarily follow such reasonable use. The question of what constitutes reasonable use must be determined in each case; but it has been

always understood that to discharge sewage, filth or deleterious waste material into a stream constitutes an unreasonable use.

The above is a general principle of common law and is independent of statutory provisions. This principle is of universal application, except in certain arid regions where the value and use of the land depend entirely upon the water supply. In such regions the principle of prior appropriation prevails, and this gives to certain owners the right to use the water from a stream to a specified extent — regardless of injury to owners below.

Necessity for State Supervision. — Common law has always afforded means by which private riparian owners injured by polluted streams can be heard in court, but the conditions of to-day demand more thorough means for protecting inland waters. The settlement of the country and the rapid growth of cities and towns have made necessary the use of certain streams for drainage purposes; and at the same time many municipalities are obliged to depend upon these same streams for their water supplies. Furthermore, to quote from a message of the governor of Pennsylvania, in 1905, to the legislature: "It is high time that attention be given to the preservation of our streams, gifts of God to humanity, which are essential to happiness and comfort and even to life. In Western Asia are vast lands where once were teeming civilizations, now barren wastes, because the people did not understand how to take care of their water supplies. Our streams are losing both beauty and utility, and are being encroached upon by filling along their banks, and using them as dumps for the refuse and pollution which comes from mills, factories and habitations."

These conditions clearly point to the necessity not only for specific statutory provision against stream pollution, but for supervision by some state or central authority whose duty is to investigate all matters relating to stream pollution and to see that sewage and other polluting substances are not allowed to enter in an unpurified state any stream or lake where a water supply would be endangered or where offensive conditions would result. By such arrangement much unnecessary litigation is avoided, and there are protected large numbers of persons, as well as municipalities, who, because of ignorance in sanitary matters, or because of the fear of becoming engaged in lawsuits, would fail to protect themselves. Through administrative control by the state, instead of adjustment through the courts alone, the future condition of our streams and water supplies can be

given much more weight; so that with the growth of the country, polluted streams will decrease instead of increasing in number.

Whenever the pollution of a stream or other body of water injuriously affects the health or materially interferes with the peace and comfort of a large but indefinite number of people in the neighborhood, such pollution is known as a public nuisance. But the public has, under these circumstances only, according to common law, the right to prevent the pollution of waters. When, however, there is a public ownership of the banks of a stream, as in the case of a source of water supply owned by a municipality, or a company which supplies the inhabitants of a municipality with water, then the public as a riparian owner is interested in the enforcement of the rights of such owners discussed above, and it is the duty of the public authorities to cause the abatement of any harmful pollution. The principles of common law under which municipal officials may cause such abatement are practically the same as those which apply to the individual riparian owner.

Unless specially forbidden to do so by statute, cities may use streams for the discharge of sewage and other filth; provided, that by so doing no injury is caused to the property down stream. If such injury is caused by a city to even a single riparian owner, then the city must properly compensate such owner or remove the pollution. This principle is well illustrated by the experience of the city of Columbus. This city, out of respect for the rights of a few farmers owning land along the Scioto River below town, is now spending $1 200 000 in extending the sewerage system and building purification works. It might be added that this respect for the rights of the farmers did not appeal strongly to the city authorities until the city has been compelled, after litigation, to pay heavy damages on account of polluting the river.

The above facts show that although common law affords a certain amount of protection, yet constant supervision by a state department, backed by statutory authority, is much more effective in securing the proper restriction of stream pollution, especially as regards the future growth of the country.

Status of Existing Legislation. — Countries and states in which the population is most dense seem to have given, out of necessity, the most thought toward preventing and regulating the pollution of streams.

Probably the most thickly-settled country, where first-class

sanitation exists, is England.* The total population of England is 30 800 000 and the area is 50 867 sq. miles; thus giving an average population of 606 per sq. mile. The population in the central part of England, or the county of Lancashire, is 4 437-500 and the area 2 030 sq. miles, thus giving a population of 2 190 persons per square mile. In order to compare this with American conditions a table has been prepared, showing the total population and population per square mile of several of our states.

State.	Population.	Area in Sq. M.	Population per Sq. M.
Massachussetts	2 420 982	8 315	291
Rhode Island	428 556	1 250	343
New York	7 268 012	49 170	148
Pennsylvania	6 302 115	45 215	139
Delaware	184 735	2 050	90
Ohio	4 157 545	41 060	101
Kansas	1 480 495	82 080	18

From inspection of the above table, it will be seen that the density of population in the central part of England is seven times that of Rhode Island, which is our most densely populated state, and twenty-one times that of Ohio. As another way of considering the density of population, it may be noted that there are in England practically as many cities of more than 50 000 inhabitants as there are in the United States; while the area of the United States is seventy-five times that of England.

Although the English Rivers Pollution Commission, established in 1868, performed valuable service in investigating methods of sewage disposal, the present English legislation regarding the prevention of the pollution of streams is based on the Public Health Act of 1875 and the Rivers Pollution Prevention Act of 1876. These acts prohibit the discharge of sewage, refuse and manufacturing waste into any stream where the purity and quality of the water would be affected thereby. A marked distinction is made, however, between cases where sewage was being discharged before the passage of the law and cases where the discharge has been commenced since that time. In the former case, the discharge of sewage was not deemed an offense, if it could be shown to the satisfaction of the court that the *best practical and available means* were being used to render the sewage harmless. It is said that this phrase, " the best practical and available means," has caused the act to become practically

* Mr. Geo. C. Whipple in Report on Sewage Disposal for City of Paterson, N. J.

inoperative, for the reason that the views of the various local authorities who are called upon to enforce the act vary so widely with reference to the definition of what constitutes the best practical means. Then by placing the enforcement of the act with the local officials it often happened that such officials were the greatest offenders in regard to the pollution of streams and were consequently not enthusiastic in regard to improving conditions.

A distinct advance was made in 1888 by the enactment of a law which placed the enforcement of the Rivers Pollution Act with the county authorities; and which gives to the Local Government Board (a national body) power to appoint joint committees representing the interests affected and investing them with ample power.

One of the most important committees appointed by the Local Government Board is the Joint Committee for the Mersey and Irwell Watersheds, established in 1892. The West Riding of Yorkshire Committee, another important one, was appointed in 1894. These committees were directed and empowered to enforce certain laws regarding the pollution of streams, and they were given ample authority to study all problems regarding the purification of sewage. The territory under the jurisdiction of these two committees is 4 800 sq. miles, and the population affected is 5 200 000. The acts of these committees must be approved by the Local Government Board, which board, as is well-known, must approve the expenditure of all money by municipalities.

As a practical illustration of the work done by the Yorkshire Joint Committee, it may be mentioned that in 1892 there were but thirty-two municipal sewage works in operation, whereas there were in 1904 eighty-five under the committee's charge.

In 1898 there was established a royal commission on sewage disposal, whose function it is to study in detail all methods of purification, with reference to advising the Local Government Board and other authorities. The final report of this commission has not yet been issued, but it is expected that this report will appear during the coming summer. Its publication is looked forward to with much interest by sanitarians all over the world.

The Constitution of the United States contains no provision which gives to Congress, generally speaking, the jurisdiction over the pollution of waters of this country. This condition

exists, no doubt, because at the time the Constitution was adopted the great importance of the subject from an interstate point of view was not thought of; hence, by the principle of state rights, each state has full power to regulate pollution of streams except where such powers are restricted by the national Constitution, or especially delegated to the national government.

Under these circumstances, uniformity of legislation in the various states is not to be expected. The natural conditions in different parts of the country are so various, the density of population and the public intelligence as to the deleterious effects of water pollution vary so widely, that the statutory regulation must necessarily differ. Those states which are most advanced in the matter of sanitation have become so through placing the control of stream pollution in the hands of some state department whose special duty it is to look after this matter.

In a paper by Mr. Edwin B. Goodell, published in 1905 by the United States Geological Survey, the states and territories are grouped into three classes: First, those having partial statutory restrictions against stream pollution; second, those having general statutory restrictions; and third, those having severe statutory restrictions.

Class I. — States with partial restrictions:

Alabama, Arkansas, Delaware, Florida, Georgia, Idaho, Iowa, Kentucky, Michigan, Mississippi, Montana, Nebraska, Nevada, North Dakota, Oklahoma, Rhode Island and Wisconsin.

In this class are found states where there is nothing more than a simple provision making it a crime to poison wells and springs. There is manifest in their legislation no sense of the general desirability of protecting public water supplies, but rather a desire to guard against certain criminal acts which would injure special groups of persons whom the legislature desires to protect.

Class II. — States with general restrictions:

California, Colorado, Illinois, Indiana, Louisiana,* Maine, Maryland, Missouri, New Mexico, North Carolina, Ohio, Oregon, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia and Wyoming.

In this class are those states and territories whose legislatures recognize the necessity of pure drinking water for every inhabitant. These laws are general in their application, and vary much as to the remedies and penalties provided; but in every case it is clearly set forth that all streams and water

* Legislation passed in 1906 places Louisiana in this class.

supplies are to be carefully protected, and the penalty for breaking the law is by no means insignificant. For instance, the Ohio statute, which is representative of this class, says: "Whoever . . . corrupts or renders unwholesome or impure, any watercourse, stream or water . . . shall be fined not more than $500."

Class III. — States with severe restrictions:

Connecticut, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania and Vermont.

The third class might be included under Class II, but it is distinguished from Class II by the fact that the states have adopted, in addition to the general laws, more definite and stringent laws to enforce the right of their citizens to unpolluted waters. These states all have active health departments specially authorized to act as guardians of the streams and to control matters relating to water supply and sewerage. Laws representative of this class will be discussed below in connection with the work of the state health departments.

In considering these three classes, it should be borne in mind that the states with the most stringent laws are not necessarily the most effective in securing pure water supplies and unpolluted streams. In order to obtain best results, the public and especially the local officials must be so educated that they will realize the importance of proper sanitation. It is more essential that a state board of health or other supervising body have funds and assistance enough to keep in touch with all local conditions within its jurisdiction, so that it can properly advise and coöperate with the local officials, than that the statute books be loaded with stringent health laws with nobody to intelligently enforce them. There are always some cases, however, where nothing but the enforcement of strict laws would be effective.

It will be noted from the above discussion, that public opinion, in both this country and abroad, is steadily progressing in the enactment of laws to enforce the rights of riparian owners and to protect the public health.

Work of the State Health Departments in the United States.

All the states in the Union, with the exception of one, Idaho, have state health departments or state boards of health. The first state to establish such a board was Louisiana in 1855. Massachusetts followed in 1869. In passing, it is interesting to note that although the Louisiana state board of

health was the first board created, the legislature of that state failed until 1906, fifty-one years later, to pass any laws for the protection of public water supplies.

The duties of the state boards of health were at first principally advisory; but in recent years legislatures have granted more authority, so that most state boards now have abundant executive powers in matters relating to quarantine, contagious diseases, and the disposal of dead bodies. A comparatively small percentage of them, however, has much authority in regard to, or are active in, the work of protecting the purity of public water supplies; although each year more attention is being given to this important feature of state health work.

The eight states listed above, under Class III, together with Indiana and Ohio, are probably at present doing the most work in this respect. Very few of these ten state boards of health, however, have power to change existing conditions when this means any considerable expenditure on the part of a municipality or water company; but all of them have power to control the increase of pollution. I will discuss briefly the work of some of those boards which are giving the most attention to matters relating to the protection of water supplies and the purification of sewage.

Massachusetts. — Massachusetts is considered the pioneer among states in her work of protecting the purity of inland waters. As long ago as 1878 an act was passed making it unlawful to discharge sewage or other polluting material into any stream used for a public water supply, within 20 miles above the location of the intake. The old theory of the "self-purification of streams" was apparently the reason for assuming that 20 miles would be a safe distance. The state board of health, founded in 1869, was reorganized in 1886, and during the next few years laws were passed, giving to this board general supervision over all public water supplies, directing all local officials to ask its advice before carrying out any proposed water supply or sewerage plan, and in addition, giving it power to remove any source of pollution within 100 feet of the high-water mark of any stream or pond used as a public water supply. These laws were later amended so as to give the state board of health, upon request from the city or town, power to make rules and regulations governing the entire watershed above any water supply intake. Provision for enforcing these rules and regulations was also made. Exceptions, however, were made in the cases of the watersheds of the Merrimac and Connecticut rivers

and of so much of the Concord River watershed as lies within the city of Lowell. Streams under control of the Metropolitan Water Board were also exempted from the jurisdiction of the state board of health.

The great success of the Massachusetts state board of health has been due in a large measure to the fact that it has been empowered, from the beginning, to make extended experiments and investigations, and has thereby accumulated a great fund of information relating to local problems. As mentioned above, the law simply requires cities and towns to ask the advice of the board, but does not require them to follow it. The fact that this advice almost always is followed, however, indicates that the work of the board has been appreciated. Thus when it became necessary to make extended investigations for the Metropolitan Water Supply District, consisting of Boston and surrounding cities, the state board of health was given direction of the investigations and the work was accomplished more thoroughly and more quickly than a temporary commisson could possibly have done it. The same is true of many other special investigations which the legislature has from time to time ordered the board to make.

One of the most prominent features of the work of this board has been the experiments upon purification of water and sewage, which have been conducted at the Lawrence Experiment Station during the past twenty years. The reports upon these experiments are now regarded as classics on sewage disposal, being constantly referred to and quoted by engineers in this country and abroad.

In certain instances, notably in the case of the Neponset River watershed, the legislature has given to the Massachusetts state board of health absolute jurisdiction in removing such sources of pollution as rendered the stream offensive, regardless of whether or not a public water supply was involved. As the pollution of the Neponset River consisted principally of manufacturing wastes, the abatement of this pollution necessitated careful studies, on the part of the state board of health, with reference to the best means of purifying these wastes without undue expense to the manufacturer. Studies of the purification of paper mill waste, tannery waste, woolen mill waste, silk mill waste, ink works refuse, and other wastes, have therefore been made; and the results of these are of great value, not only to the state of Massachusetts but to all other states.

In connection with removing gross pollution from rivers, the

board has made careful inquiry into the relative proportion of sewage and stream flow which may obtain without causing a nuisance. The general conditions, including the population, on the watersheds of some twenty-seven rivers were carefully studied; and frequent chemical analyses as well as inspections were made, for a period of two or three years, of the river water. Upon tabulating results, it was found that it is necessary, in order to avoid rendering streams offensive to sight and smell, that the flow of any given river amount to at least $3\frac{1}{2}$ cubic feet per second for each 1 000 persons discharging sewage therein; and that in some cases a flow of 6 cubic feet per second per 1 000 persons discharging sewage was necessary in order to avoid a nuisance.

For over twenty years, therefore, the Massachusetts state board of health has been keeping a constant supervision of all existing water supplies, conducting experiments and investigations on water and sewage purification, advising local officials with reference to their problems, and abating to a large extent the gross pollution of certain rivers. This admirable sanitary work has been rewarded by a distinct improvement in the public health, as indicated by the low average of the typhoid rates in the cities of Massachusetts during the last ten years. This rate is only about 20 per hundred thousand, which is but one-third or one-fourth of the average rate for the cities of Ohio or Pennsylvania. Almost without exception, the water supplies of Massachusetts are safe, and a stranger within the boundaries of the state need have little fear of drinking impure water.

New York. — In 1901 the state board of health of New York was discontinued and a health department under the direction of a health commissioner was established in its place. The health commissioner is appointed by the governor for a term of four years. He has full charge of the work and organization of the department. As at present organized, the department consists of a division of sanitary engineering, division of laboratory work, division of vital statistics, division of communicable diseases, and division of publicity and education. This organization has been in force for two years and promises to accomplish very effective results.

All plans for proposed sewerage and sewage disposal must be approved by the health department before being carried out; and this department may impose such conditions regulating the discharge of sewage, as well as manufacturing wastes, as it deems proper.

As yet there is no law in New York which makes it necessary that all proposed plans for water works be approved, although there has been in force for nearly twenty years a law by which the state health department (or formerly the state board of health) is required to make rules and regulations for the protection of the watersheds of streams used for domestic purposes. Ample provision is also made for enforcing these rules and regulations, even though in carrying them out it necessitates building sewage purification plants. Every local water works official is required to make such inspection of the watershed as the state health department may direct.

Pennsylvania. — Two years ago the legislature of Pennsylvania created a state health department to supersede the former state board of health. This new department, similarly to New York, is under the supervision of the commissioner of health. The powers conferred upon the department are very great, not only as regards the general work in controlling infectious diseases and in keeping vital statistics, but especially as regards the control of water supply and sewerage problems. It is probable that no legislature at a single session ever enacted such sweeping health measures and appropriated so much money ($350 000) to carry them out.

A very important part of the department of health is a division of engineering, the special function of which is to carry out the provisions of an "Act to Preserve the Purity of the Waters of the State for the Protection of the Public Health." Under this law, every municipal or private corporation is obliged to file with the department of health, certified copies of complete plans, surveys and description of the water works under its charge. No new water supply can be placed in use and no addition can be made to an existing supply without a written permit from the commissioner of health.

In a similar manner, all municipalities are required to file with the department of health, plans and information concerning sewerage systems and sewer outlets. No sewage can be discharged into any stream without a permit from the commissioner of health, through any sewerage system which has been extended since the passage of the act (1905).

As nearly every municipality is called upon to make sewer extensions every year, it is clear that all sewer outlets in the state will soon be under control of the health department. The permit of the commissioner of health can be revoked whenever it is considered that there are being created conditions

injurious to the public health. This makes it possible for the health department to require the sewage of any municipality to be purified when necessary. This law also applies to manufacturing wastes, except drainage from coal mines and tanneries.

Vermont. — The powers of the state board of health of Vermont are similar to those of Massachusetts and New York in regard to the making of rules and regulations protecting water supplies; and they are also similar to those of Massachusetts in that all local officials and manufacturers are required to consult the state board of health before adopting any system of water supply or sewerage.

There is one important feature of the Vermont law, however, which in a way places it in advance of any other state. This is the law which gives to the state board of health authority "to prohibit any town, city, village, public institution, individual or water or ice company from using water or ice from any given source whenever in its opinion the same is so contaminated, unwholesome and impure that the use thereof endangers the public health. And the court of chancery shall have jurisdiction and power, upon application therefor by the state board of health, to enforce by proper order and decree any order, rule or regulation which said board may make under and by virtue of this section."

This law, although passed only three years ago, has already been enforced by the state board of health in the cases of four or five cities, including the city of Burlington, where the water was shut off from all public fountains and public buildings, with the consequence that the citizens soon arranged to build a filtration plant.

Ohio. — Although Mr. Goodell's classification places Ohio in the second class, *i.e.*, with states having only general laws for the protection of water supplies, yet these general laws have been used to advantage, and consequently Ohio is considered by sanitarians all over the country as distinctly a leading state in public health work, including the protection of water supplies and the purification of sewage.

The Ohio state board of health was created in 1886. The board was given the usual general powers regarding the control of epidemics and infectious diseases. It was also given advisory powers regarding public water supplies and sewerage; but had no absolute authority over these. The board is composed of seven members, one being appointed by the governor each year.

In 1893, at the time of the cholera epidemic at Hamburg,

when some cholera cases were being imported into this country, the Ohio legislature realized the importance of protecting public water supplies, and therefore increased the authority of the state board of health along these lines. The present law, as passed in 1893, reads as follows: "It [the state board of health] shall respond promptly, when called upon by the state or local governments and municipal or township boards of health, to investigate and report upon the water supply, sewerage, disposal of excreta, heating, plumbing or ventilation of any place or public building; and no city, village, corporation or person shall introduce a public water supply or system of sewerage, or change or extend any public water supply or outlet of any system of sewerage now in use, unless the proposed source of such water supply or outlet for such sewerage system shall have been submitted to and received the approval of the state board of health."

Since 1893, therefore, it has been necessary that all plans for new projects for public water supplies or sewerage be approved by the board. In regard to works in existence previous to 1893, the board has no jurisdiction except to investigate and point out to local officials any conditions which need improvement. This lack of control over existing works is a weak point in the present sanitary laws of the state and is the feature which prevents Ohio from being placed in the same class (as regards stringent legislation) with such states as Massachusetts, Vermont and Pennsylvania. It is expected, however, that the present legislature at its next session will strengthen the existing law.

In 1898 legislation was enacted, authorizing the state board of health to establish and maintain a laboratory for the chemical and bacteriological examination of public water supplies and of sewage effluents; in addition, pathological work was provided for. The board was directed to annually examine and report upon the condition of public water supplies.

About this time the board also established an engineering department for the purpose of making careful investigations of the proposed water supply and sewerage projects which came before it for consideration, as well as for studying the conditions of existing works.

During the years 1897 to 1902, inclusive, the board has, through its engineering department laboratory, and with the aid of other temporary expert assistance, made a detailed study of the watersheds of all the principal rivers in the state. One or two watersheds were taken up each season. These studies included an investigation of all sources of pollution both from

cities and villages, as well as from factories. All sewerage systems and water works were examined in detail, and the population using such works was determined. Chemical analyses of the rivers themselves were made at regular intervals, and the pollution of the water, in many instances, was thereby conclusively demonstrated. The results of these investigations, including maps and statistical information, will be found in the annual reports of the state board of health. These reports afford a very comprehensive view of Ohio conditions as regards stream pollution.

Supplementary to the above work, stream gaging stations were established on certain rivers; and these were later maintained for several years by the United States Geological Survey, under the immediate direction of the engineer of the state board of health. Daily gage readings and records of discharge, covering periods of from six months to three years, of some fifteen of the rivers of Ohio are now available. These have been of great service in studying sewerage problems and also in other work.

During 1905 the board, acting coöperatively with the Hydro-Economic Division of the United States Geological Survey, made a detailed study of the disposal of certain industrial wastes which had long been sources of complaint. Much valuable and practical information was gained in regard to the purification of dairy refuse, woolen mill waste, acid iron waste from tube works, and the refuse from distilleries. The work on this last was especially interesting, as a method was developed whereby the valuable ingredients in the refuse could be reclaimed at a very substantial profit to the distiller. The owners of the distillery at Lynchburg, Ohio, instead of spending money to defend themselves against law suits for stream pollution, now have an income from the sale of their treated refuse.

In 1906, on account of the increased responsibilities of the board, due to the many important projects for water supply and sewerage which were submitted to it for approval, the legislature made a special appropriation to enable it to increase its engineering and laboratory force sufficiently to make a detailed examination of the construction, methods of operation and efficiency of all existing water and sewage purification works in the state.

At the present time, therefore, the Ohio state board of health is giving a great deal of attention to the problems of water supply and sewage disposal. The routine work of the engineering department consists in making reports upon the

proposed schemes which are continually being submitted, in responding to the calls of local officials for advice, in inspecting the construction of new work in order to see that it is being carried out in accordance with the approved plans, and in making, as far as possible, regular examinations of existing water supplies.

The special work consists of a series of detailed inspections of the water purification and the sewage purification works in operation in this state. One of the assistant engineers devotes his entire time to the water purification works and another to the sewage purification works. Each visit usually occupies two or three days during which, in case of water purification works, samples of raw and of filtered water are collected, for analysis, at frequent intervals; and observations of the rates of filtration, coagulants used, and of other features are carefully made. The bacterial samples are all plated, and most of the other analytical work is done, at the plant. This avoids the undesirable feature of shipping the samples by express. A corresponding procedure is followed in the inspection of sewage plants.

This water and sewage work has proved of very great value, not only on account of the information which the board has gained for use in acting upon future plans, but also because the work has served generally to educate and interest local officials in their own plants. In a few cases the plants have been materially changed, on the strength of the board's recommendations, and their efficiency greatly increased. At four of the larger sewage plants, the operators have been trained to make each day simple chemical and incubation tests of the purity of the effluents. At both the sewage and water plants, in the majority of instances, the superintendents are furnishing the board with daily records of the principal features of operation.

The importance of water filtration to the people of Ohio is very great. The difficulty of obtaining abundant ground water supplies makes it necessary for all of our large towns and cities to depend upon surface waters, which in nearly every case require filtration, either because of sewage contamination or because of turbidity or for both reasons. At present, in Ohio, water filtration plants are in operation in fourteen municipalities, having an aggregate population of 175 000 people. Within a year, plants at Cincinnati, Columbus and Toledo will be completed; and then the above figure will be increased to over a million people. Ohio will then lead all other states, excepting possibly Pennsylvania, in the per cent. of her population served with filtered water.

The small dry-weather flow of most Ohio streams and the

building up of communities along their banks, have made the problem of sewage disposal an important one in this state. At present there are 35 sewage purification plants in operation in Ohio. Nineteen of these are municipal plants and 16 institutional. Plans for some 30 more have been acted upon by the state board of health and some of these are now in process of construction. By far the largest plant in the state is the one now being built at Columbus. When this is done the total population in Ohio tributary to sewage purification works will be nearly 300 000.

One of the most important problems with which the board has to deal is the question of the degree to which a given sewage must be purified. There are many factors which affect this question. A single standard of purity applicable to all cases is not tenable. In cases where it is not necessary to protect a water supply, or dairy, shell-fish or market garden interests, there is obviously no need of purification greater than that obtained by removing most of the suspended solid matter and rendering the liquid, together with the small amount of solid matter which may remain in it, non-putrescible; that is, the purified sewage must be fairly clear and must not putrefy and become offensive on standing indefinitely at as high a temperature as 98 degrees fahr.

Where the stream receiving the effluent is used for public water supply purposes, the problem takes on an economic aspect and the question arises: Ought a municipality to be required to increase the cost of its sewage works, say two or three times, and transform its sewage into a potable water for the purpose of protecting a water supply many miles down the stream, when the stream through its numerous tributaries undoubtedly receives a greater or less amount of miscellaneous pollution before reaching the water supply intake? Ought not all dangerous organisms which may come from the sewage works or from elsewhere on the watershed to be removed by water filtration works operated by the municipality or company owning the water works? Especially is the last question significant if water filtration works are already in operation.

It is necessary to carefully weigh the conditions governing each case in order to arrive at a just decision. There are natural agencies of purification in every stream; but so far as the removal of dangerous bacteria is concerned the value of these agencies is uncertain. This is on account of constant fluctuation in the velocity and volume of stream flow, changes in temperature, changes in chemical and physical composition of the water, and

other factors. According to the official statement of the Rivers Pollution Commission in England in 1868, "There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source." Subsequent experience in England, as well as in this country, has to a large extent borne out the significance of this statement. Swift-running rivers, contrary to the usually accepted theory, are more dangerous than sluggish streams in regard to conveying pollution; for with the latter, pathogenic organisms are longer subjected to "unfavorable environment." Dilution is an important factor in purifying a stream, but cannot be counted upon to remove all harmful matter of sewage origin.

All things considered, it seems unjust to allow a community to discharge into a stream used as a water supply any disease producing organisms, the destruction of which can be effected without unreasonable difficulty; provided, of course, that the sewage works are located at such a distance from the water supply that the natural agencies above discussed cannot be depended upon. In other words, the water filtration works should not be given an extra burden to perform. This is especially true under the usual American conditions, where the care of water filters is often intrusted to careless or incompetent management. Water-works officials, whether they operate a filtration plant or not, have a right to expect that as much pollution as possible be kept out of the sources of supply, at every point; and that the water be as pure as is practicable to make it before arriving at the intake. "Innocence is better than repentance."

To purify sewage to the high degree above discussed means considerable added expense. Either sand filters of ample area must be installed for the final treatment of the sewage effluent, or there must be provided some means for disinfecting with chemicals the effluent from works which only purify the sewage to the non-putrescible state.

The Ohio state board of health has required sand filters to be added to proposed works in several instances where the effluent was to be discharged into a stream used as a water supply. The practicability and efficiency of the disinfecting process, however, is one of the most recent developments in the art of sewage purification, and it is not yet definitely settled whether this method will be practicable under all conditions. It is reported to have been used in England at several places with

good results. Chlorine, or its compounds, seems to have afforded the best and most economical results. This substance can be produced electrolytically from salt water at small expense.

By way of coöperation in working out this problem, the Bureau of Plant Industry United States Department of Agriculture, has for the last eight months placed at the service of the Ohio state board of health two bacteriologists; and under the direction of the board these men have been making thorough tests of the treatment of effluents from different sewage purification plants, with both sulphate of copper and chloride of lime or bleaching powder, which when decomposed produces chlorine.

One of the most important series of tests has been made at Marion, Ohio, where the effluent from the sewage works is discharged into the Scioto River, forty-five miles above the Columbus water supply intake. It is believed from the information recently gained in these experiments, that a sewage effluent can be freed from pathological organisms without undue difficulty and expense. This process will be a great protection to water supplies in the future, especially at times of epidemics.

The complete report upon the special investigation of the board into water and sewage purification, including the disinfection of sewage effluents and the softening of water, will be published about a year hence.

Recent Agitation on the Part of the Engineering Societies of Ohio for the Prevention of Stream Pollution.

Before closing, I wish to call attention for a minute to the recent movement, among the engineering societies of Ohio, in regard to future protection of the streams of this state and also of Lake Erie. On May 11, 1906, representatives of the Ohio Engineering Society and the Engineers' Clubs of Cleveland, Cincinnati, Toledo and Columbus, respectively, met at Columbus to consider matters relative to the pollution of public water supplies. Organization was effected and the committee was called the "Joint Committee of the Engineering Societies of Ohio for the Prevention of Stream Pollution." Mr. Walter E. Rice, a member of your society, was elected chairman, and the speaker, secretary. Sub-committees were appointed as follows: Committee on legislation: committee on ways, means and scope; and committee on statistics. Each of these sub-committees is to make a report at the next meeting of the Joint Committee, and a general procedure will be decided upon for obtaining legislation in this state and in other states bordering the Great Lakes, for protecting the purity of inland waters.

DISCUSSION.

Mr. A. Elliott Kimberly. — From Mr. Pratt's clear presentation of the subject of the protection of water supplies, it is apparent that the question of their control should rightfully be invested in a central or state authority, clothed with laws giving administrative as well as advisory power. Under these conditions it justly may be asked, To what extent shall such authorities carry demands for water supply protection? What shall be the limit of sewage purification required, in cases where the sewage problem of one city is correlated to that of the water purification problem of an adjacent city?

Leaving the question open to be decided more properly perhaps by local conditions, as suggested by Mr. Pratt, there arises the thought as to the degree of purification to which sewage can be subjected in a practical way in the light of present information. Since the removal of the offensiveness of sewage has long since reached a state of practical accomplishment, developments well known from the construction and operation of purification plants on a practical scale, as a further step in advance there suggests itself the feature of producing an effluent of bacterial as well as of chemical purity. This phase of the question, as Mr. Pratt states, has been discussed considerably abroad, but American tendencies in this regard are of more recent date. Information as to the disinfection of sewage effluents in this country is probably confined to experiences with copper sulphate treatment at Vineland, N. J. (1905),* to laboratory experiments carried out at Columbus, Ohio (1906),† and to a study of sewage effluent disinfection carried out on a laboratory scale by Phelps and Carpenter at Boston (1906).‡ Some work along this line, particularly the use of chloride of lime or bleaching powder, was suggested by Phelps for the treatment of the effluent from a septic tank at Redbank, N. J. (1906).§

In the latter part of 1906 there was begun in Ohio a study of the disinfection of sewage effluents on a practical scale under

* Newcomb, Edwin L.: New England Water Works Association, December, 1905, Copper Sulphate Symposium.

† Johnson, G. A., and Copeland, W. R.: "Copper Sulphate as a Germicide." *Journal of Infectious Diseases*, I, Supplement No. 1, p. 327.

Johnson, G. A.: Report on Sewage Purification, Columbus, Ohio, 1905, pp. 471–479.

‡ Phelps, Earl B., and Carpenter, W. T.: *Technology Quarterly*, XIX, No. 4, p. 382, December, 1906.

§ State Sewerage Commission, New Jersey, Report 1907, p. 252.

a coöperative agreement between the United States Department of Agriculture, Bureau of Plant Industry, and the Ohio State Board of Health. These experiments were probably the first to be carried out in this country on the disinfection of sewage on a scale comparable to practical requirements. The work embodied a study of the practicability of disinfecting comparatively large volumes of sewage effluents with the use of copper sulphate and chloride of lime or bleaching powder. The problem was studied at Westerville, Ohio; Lancaster Boys' Industrial School, a state institution near Lancaster; and at Marion, Ohio.

As a preliminary to the studies at each of the above stations, facilities were provided for the control of the application of the disinfectant, for the continuous measurement of the effluent flow and for a certain storage period of the treated effluent. The actual experiments included full bacterial and chemical analyses of composite and average samples collected throughout the period of a test, the greater part of the work being carried out in the field with the aid of a portable laboratory.

As disinfectants, both copper sulphate and chloride of lime were studied, the former in extension of the Bureau of Plant Industry's algæcidal work, and the latter, a development from current thought in England, from German practice and from suggestions from Phelps and Carpenter's experiments at Boston on sewage effluent disinfection. For a detailed account of these tests, reference should be made to Bulletin 115 of the United States Department of Agriculture, Bureau of Plant Industry, and also to the forthcoming report of the Ohio State Board of Health's special investigations of water and sewage purification plants. Suffice it here briefly to refer to some of the interesting indications brought out by the experiments, as suggesting that the protection of water supplies from sewage effluents is a problem of much practical possibility even for continuous treatment, and assuredly for emergency use in times of epidemics.

The data obtained were average results from the treatment of the entire volume of sewage flow during the period of disinfection, which was continued for from six to eight consecutive hours at each run. The following table shows the quantity and the kind of sewage treated at the different plants:

SUMMARIZED STATISTICS OF DISINFECTANT EXPERIMENTS.

Station.	Number of Runs. Copper Sulphate.	Chlorine.	Duration of Test (Hours).	Kind of Effluent Treated.	Rate of Flow, Gallons in 24 Hours.
Westerville..........	16	–	8	Continuous contact.*	41 000
Lancaster...........	10	3	8	Intermittent sand.	160 000
Marion.............	9	3	6	Subsidiary sand.	600 000
Marion.............	1	3	6	Contact.	600 000
Marion.............	–	9	6	Septic tank.	600 000

*Contact filters of cinders operated on continuous basis, outlet open. Surface not submerged.

As discussed in Bulletin 115, very satisfactory results were obtained with both copper sulphate and chloride of lime. Copper sulphate appeared the more limited as regards its adaptability to practical conditions, in that its efficiency is perhaps more dependent upon a high-grade sewage effluent, together with a required storage period of at least 3 hours; chlorine, as bleaching powder, on the other hand, requires less storage and is less susceptible to organic matter.

The indications drawn from these studies were, briefly, that a sewage effluent (Lancaster, 160 000 gal. daily) of a purity equal to that from efficiently operated intermittent sand filters may be disinfected as regards B. coli by the use of 13 parts per million of copper sulphate (109 lb. per million gallons) with a storage of treated effluent of about 3 hours and at a cost for chemical of about $6.54 per million gallons. Similar results with chloride of lime required about 4 parts per million available chlorine (134 lb. per million gallons bleaching powder containing 25 per cent. available chlorine), under one hour's storage and at a cost of $3.35 per million gallons.

With less highly purified effluents, greater amounts of copper sulphate were required, 40 parts per million (334 lb. per million gallons) applied to the Westerville continuous contact filter effluent (41 000 gal. daily) removing, however, about 99.3 per cent. of the acid-forming colonies under about one hour's storage and at a cost for chemicals of about $20 per million gallons. Chloride of lime, on the other hand, under the application of lesser amounts, appeared to be quite efficient for effluents of less stability than those from sand filters, results from the putrescible Marion contact filters showing a removal of 100 per cent. of fermenting organisms with the use of 5 parts per million of applied chlorine (167 lb. per million gallons bleaching powder containing 25 per cent. available chlorine), at a cost for chemicals of $4.17 per million gallons.

Passing to septic tank effluents (Marion), the use of as high as 25 parts per million available chlorine (835 lb. per million gallons bleaching powder containing 25 per cent available chlorine), at a cost for chemicals of $20.87 per million gallons, removed 99.3 per cent. of fermenting organisms, indications being strong that a more thorough settling of the septic effluent and the application of larger amounts of chemical would effectively destroy organisms of the B. coli type. The increased cost would, of course, be admissible in cases of epidemics, and moreover, only under such conditions would there probably ever arise the question of the treatment of a sewage effluent as putrescible and as difficult to disinfect as the effluent from a septic tank.

The idea of the occasional disinfection of sewage effluents appears to have assumed a more definite shape abroad, especially in England, where, as summarized by Rideal,* experiments have been carried on at a number of places, notably at Maiden Head, Hertford and Guilford. Some work has also been done in India,† where chloride of lime has been used for disinfecting the effluents of septic tanks. In Germany, particularly, disinfection has for some time been considered practical as a remedial measure in the case of epidemics and for continuous treatment for the sewage of hospitals. In Schmidtmann and Gunther's report on bacterial purification of sewage in Germany,‡ from data there published, it appears that out of the 18 principal plants in Germany, 8, or 44 per cent., have permanent facilities for occasional disinfection. German conditions, of course, refer to much stronger sewages than those in America, and consequently figures as to the quantity and the cost of disinfection far exceed those probably necessary in this country. Thus Schumacher's § conclusions are quoted in the above-cited report, stating that for raw hospital sewage there is required chloride of lime 1: 2000 (average available chlorine 167 parts per million) under a two hours' contact; other experiments show complete disinfection at a chloride of lime concentration of 1: 5000 (average available chlorine, 67 parts per million). As a lower limit, the quantity of available chlorine is placed for well-purified sewage effluents

---

* Rideal, Samuel: "Sewage." Third edition, 1906, pp. 179–192.

† Indian Government: "Resolutions on the Workings of Septic Tanks." Calcutta, January 6, 1906.

‡ Heft VII, "Mitteilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung und Abwässerbeseitigung, 1906."

§ "Die Desinfektion von Krankenhausgruben mit besonderer Berücksichtigung des Chlorkalkes und ihre Kontrolle." *Ges. Ingenieur.*, 28 Jahrg., 1905, pp. 361–368, 377–384, 393–397.

at 1 : 60 000, or about 17 parts per million. Information appears to be almost as indefinite in Germany as in this country, although the recent Ohio experiments have probably suggested more nearly the probable practical limitations of the use of disinfectants in relation to sewage effluents of different degrees of organic purity.

Speaking generally, it does not seem too extreme to interpret available information as regards the disinfection of sewage effluents as indicating the practicability of producing an effluent of bacterial as well as of chemical purity, the former as a remedial measure for the protection of water supplies in epidemical outbreaks, and both as an all-the-year requirement for special cases of closely related water and sewage purification plants. However great may be the advance in knowledge as to practical disinfection of sewage effluents, actual and lasting benefit will probably be assured only when central or state authorities shall have complete and final control of water supplies by powers vested in them by the legislature of the state.

Mr. Wm. S. Johnson. — The subject of Mr. Pratt's paper is of special interest to the writer since he has recently been connected with two cases in Massachusetts, where the advantages of state control of the purity of inland waters have been forcibly impressed upon him. In Massachusetts the state exercises a certain control over inland waters through its board of health, and it has sometimes been claimed that this control is so burdensome as to be an injury to manufacturers and to the state as a whole. The two cases referred to, however, indicate that better results will be secured by such control than by the ordinary process of law.

The first of the two cases is one in which a manufacturer located on a certain stream brought suit against a city which discharged sewage into the stream above the factory. The action was brought several years ago and the manufacturer has spent large sums of money in obtaining evidence and preparing the case. The city which discharges the sewage into the stream prepared to fight the case and spent still larger sums. The stream is one of the most foully polluted in Massachusetts, and no one could possibly deny that the concern which brought suit, as well as any other corporation or individual located near the stream, was injuriously affected by the foul condition of the water. The case was somewhat complicated by the fact that the stream received manufacturing wastes as well as city sewage, but the quantity of the city sewage was alone sufficient to create a

decided nuisance. The officials of the city openly stated that it was cheaper to pay considerable sums of money each year in fighting the case in the courts than to pay the cost of maintenance of expensive sewage purification works. After the case had dragged along for several years, never coming to a trial, it was withdrawn by the complainants, apparently because of certain technicalities or legal obstacles, although the case seemed, from an engineering standpoint, to be a perfectly clear one. This is a case which should have been considered by some properly constituted authority, either capable of determining the facts for itself, or empowered to employ competent experts, and without the necessity of the great expenditure of money by those affected.

The second case was brought by the owner of a small mill which had previously been used for the manufacture of paper. Some time after the shutting down of the mill, suit was brought against a large manufacturing corporation which operated a woolen mill a short distance above the paper mill. This matter has been in the courts for about five years, and recently the full bench of the Supreme Court rendered a decision ordering that an injunction be issued restraining the woolen mill from the further pollution of the stream. The question of damages is still unsettled and is now before a master.

This also is a case which has cost enormous sums and which could perfectly well have been settled by a state commission; but there is a still worse feature about this case. The decision shows that the court, after all of these years of consideration, did not in the least comprehend the situation. The stream is one which receives the direct discharge of sewage from a large town in New Hampshire only a few miles above the factory. It had been previously used for water supply purposes, but had been abandoned for this purpose on account of an epidemic of typhoid fever which was traced directly to the drinking water. The stream had been pronounced by the state board of health unfit for domestic purposes. Furthermore, it is well known that it is practically impossible to purify the wastes from a woolen mill to such an extent that they can be discharged into a relatively small stream without making the water less fit for drinking purposes. The court found, however, that "it does not appear that the offensive matter cannot readily and at small expense be otherwise disposed of. . . . Nor is this a case in which the defendant is simply discharging noxious matters into an already polluted stream. It is expressly found by the master that the water when it reaches the defendant's premises is good, clean, clear brook water, fit for any kind of manufacturing or for domestic use."

The court ordered as follows: "Accordingly a decree should be entered that the exceptions of the defendant should be overruled, and that it should be enjoined from emptying or discharging into the brook upon its premises, above the plaintiff's premises, any acids, soaps, compounds of soap, or of iron, chemicals, scourings, dye-stuffs, sewage or any objectionable substances whatever, in quantities that noticeably or appreciably affect the purity of the waters when they reach the plaintiff's premises, or render them materially less fit for drinking, domestic or other uses at that point than they are when they enter the defendant's premises."

It is hard to conceive that any commission or board charged with the control of inland waters would make a decision of this kind, applying a drinking-water standard to a stream not used for this purpose and already badly polluted by sewage discharged into it outside of the state. Furthermore, such a commission would know that it would be impossible to purify the wastes from a woolen mill of this character so that they could ever be discharged into a small stream used for drinking or domestic purposes.

In both of these cases the complainants were put to a great expense, and such is always the case when the matter is taken to court. This means that unless those who are affected by the foul condition of the stream are wealthy, they must patiently endure it or move elsewhere.

As an illustration of the different method of procedure under state control I might refer to the manner in which the law relating to the pollution of the Neponset River has been enforced by the Massachusetts State Board of Health. The law has been in effect for several years and the board has been working with the manufacturers to ascertain the best method of purifying the wastes from the many different manufacturing plants. Each case has been considered separately and an attempt has been made to secure the cheapest as well as the most efficient plan. A reasonable time has been given to make the necessary changes in the different plants, and it seems likely that the work of purifying this stream will be accomplished without recourse to the courts.

Perhaps a still more important reason for state control is that with state control it is possible to act before the damage is done, while if the matter is left to the courts, it can be settled only after the sewerage system has been constructed, or after the mill is in operation. With a state authority it is possible for the manufacturer or for a city or town to obtain advice in advance as to

whether it will be permissible to discharge sewage or waste into a stream before incurring a large expense in preparing plans or building works.

Experience in Massachusetts has shown that it is exceedingly difficult to clean up a stream which is already polluted by sewage and manufacturing wastes. The factories and the sewerage systems are constructed in such a way that it entails enormous expense to construct purification works, and in some cases it practically means the abandonment of the manufacturing plant. On the other hand, there is comparatively little hardship in so constructing the sewerage system or the manufacturing plant that the wastes can be treated in the beginning.

The state control of inland waters began in Massachusetts practically twenty years ago. Those streams which were foully polluted at that time are still foully polluted. The work which has been accomplished has been in the way of preserving the purity of the streams which were then clean and preventing the further pollution of streams which were already polluted. It is very gratifying to see that the state of Ohio is beginning right and is putting these matters under state control before the streams become so badly polluted that it will be too late.

Mr. Allen Hazen. — One of the great uses of the rivers of our country is to carry away various wastes, the disposal of which would otherwise involve serious expense to municipalities and manufacturers.

This is a most important use of the streams. It is only to be used within reasonable limits, and those limits, as Mr. Pratt intimates, are defined by law. The common law controls until it is modified or superseded by special statutes.

The restriction of the natural and proper use of the streams in this way by arbitrary and unreasonable legislation tends to tax unnecessarily and unjustly many municipalities and manufacturers. There can be no doubt that if such laws had been enacted and enforced, a generation ago, as some state authorities would like to see enforced at the present time, they would have proved a very serious handicap to the development of the country.

The common law may be a cumbersome and expensive way of determining the rights of various riparian owners and of preventing excessive pollutions of some of our rivers, but it is an effective way. It certainly has some advantages, and great advantages, over the special laws which have in many cases replaced it.

Certainly it is not to be questioned that in some cases additional and special legislation is necessary, but it seems to the writer that the greatest care should be used in framing such legislation. There are many points to be considered. Not only must a reasonable view of river pollution be taken, but the laws must provide for a reasonable procedure in determining the rights of different parties.

Under some laws that have been passed it would seem that state officers were given legislative and judicial authority not at all in harmony with our general theory of government; and when such officers exercise such judicial authority, they do it without the restraint of the traditions and rules of procedure which control our courts and insure the protection of the rights of all parties in the decisions that are reached.

Fortunately some over-stringent laws have been found unconstitutional. This is fortunate because it has prevented grave injustice to many parties, and it is further fortunate because the enactment of unduly severe laws and their enforcement certainly does not tend in the long run toward improving the sanitary conditions of the country; and this is the ultimate object which is sought by the author of the paper and by the writer.

Mr. Theodore Horton. — Since it is mainly through a knowledge of the inconsistencies in the laws relating to the purity of inland waters of our different states, gained largely from an open discussion of them, that any advance toward a uniformity of such laws can be hoped for, the writer feels that the author's paper is of especial interest and value to those under whose counsel and advice the execution of these laws is intrusted.

The writer believes that in dealing with the many and varied questions that continually arise in connection with stream pollution, no general policy or procedure can be pursued successfully or in a lasting manner in any state until there is secured among the various states, and especially those geographically contiguous, a much greater uniformity of laws and consistency in policy than now exists. This lack of uniformity is particularly noticeable in the case of the state of New York, owing to its geographical position and the interstate character of many of its streams. New York is bounded by five other states, the protection of the streams of which, as pointed out by the author, is under the control of bodies of men different in organization, working under different laws and in some cases pursuing entirely different policies. With every one of these states there are streams which flow from or into the state of New York and, in some instances, re-enter the state from which they first flow.

Under such conditions, then, it is evidently impossible for the state of New York, or any adjoining state, having a single sanitary code, to adopt a policy with respect to stream pollution that will be in perfect harmony with the policy or practices of the other states. The policy of one state must of necessity work relatively a burden or hardship upon the people or communities of other states, and this apparent injustice will usually create a discontent, and frequently a defiance, of the laws of the state where such policy is the more severe.

The writer believes that it is only through education and a coöperation among state health officials having in charge matters pertaining to stream pollution that any hope of unanimity of legislation and practices can be accomplished. This education should not be limited to a mere gain of knowledge pertaining to water supply, sewerage or stream pollution, for the exclusive use of engineering divisions of state boards or departments of health, but should be extended to local health boards and the people themselves in such a manner and to such an extent as will create a demand for effective and consistent legislation in all of the states. This principle of broader education is considered of such importance in the state of New York that under the present commissioner of health, Dr. Eugene H. Porter, a special division, entitled the "Division of Publicity and Education," has been instituted, and for more than a year has been doing effective work of education in all the branches of public health work.

Along the line of coöperation I believe much can also be accomplished. Sanitary laws in our different states will probably continue to vary somewhat, partially as to result of differences in local and even social conditions, but principally owing to a failure to enact new laws or amend older ones to keep pace with the advance in knowledge and experience gained in some states where greater opportunities or funds are available for gaining such knowledge and experience. A closer intercourse between representatives of health boards of all states would, then, do much in guiding the progress of health work in states less advanced in matters of sanitation and in conserving considerable work and funds now expended independently by different boards in investigations and solutions of identical problems. It would also tend to secure a greater harmony of opinions and practices among all of the states and eliminate the non-uniformity in laws and policy which, the writer feels, is the greatest barrier at the

present time to progress in protecting efficiently and consistently the purity of our inland waters.

Whether the practical application of this idea of closer co-operation can be better accomplished by more formal conferences between health representatives of different states, such as by the joint conference held at Atlantic City in August, 1906, between the heads of the state departments of New York, New Jersey and Pennsylvania with reference to the pollution of the Delaware and Susquehanna rivers; or whether by less formal conferences or meetings between the engineers representing such departments, such as the writer has also had the pleasure of attending on a number of occasions during the past year, is of less importance at this time than the spirit which has prompted these conferences. The unanimity of ideas and purposes which has followed the discussions at these conferences has certainly convinced the writer of the value of such coöperation and given him the hope that this principle can be extended in a practical way to the mutual benefit of all state departments of health.

Prof. C.-E. A. Winslow. — I am inclined to think that when the history of the early twentieth century in the United States is written, one of its most important chapters will deal with the progress of sanitary reform. The adjustment of public and private economic interests at the moment occupies a large share of our attention, but its effect upon human life and human happiness will not equal that of the quiet movement toward purer food and purer water, better factories and better homes. Particularly in water supply and sewage disposal, the last ten years have marked almost an epoch. During that time the cities of Cincinnati, Indianapolis, Jersey City, Louisville, Minneapolis, New Orleans, New York, Philadelphia, Pittsburg, Columbus, Toledo and Washington, with an aggregate population of over eight millions, have carried out or projected important plans for the improvement of the sanitary quality of their water supplies. All through the smaller cities the leaven is working, and progress is being made with special success, under the impulse of aggressive state sanitary authorities, in the commonwealths of New York, Pennsylvania and Ohio. Mr. Pratt's well-balanced statement of the legal principles underlying the campaign for the protection of inland water, and his able review of the progress already made in various states, is, therefore, particularly timely.

There is no longer any valid excuse for infected water

supplies or polluted streams. The development of the process of mechanical filtration has made water purification practicable for all parts of the country. The conviction is steadily growing that no surface supply is safe without treatment, either by slow sand or mechanical filters. Protection of water sheds and storage are useful accessory agents, but the safety that comes from perfect control can only be attained by the use of a naturally or artificially filtered supply.

In sewage disposal, too, the engineer has at last a fairly satisfactory series of methods available for practical application. The work of Cameron, Dibdin and the other English sanitarians in the development of the septic tank and the trickling filter make it possible to secure a stable effluent without excessive expense, even for large cities, in regions where natural sand beds are not available. This solves the problem of purification as far as putrescible organic matter is concerned. The effluents from filters of coarse material are not, however, bacterially purified, and in certain cases bacterial as well as chemical purity is necessary. This fact has turned the attention of sanitarians to a fresh consideration of the problem of removing bacteria. Its solution has not been long delayed. Chemical disinfection of effluents has now been clearly shown to be feasible, and some of us believe that, in certain cases, even crude sewage or septic effluent may be bacterially purified in this manner with advantage. As Mr. Pratt has pointed out, the idea of chemical disinfection, like the practice of sewage treatment at high rates, originated in England.* It is fair to remember, however, that we owe the serious consideration of this process by American engineers to the demonstration of its economy a year ago by Phelps and Carpenter.† Further work now being carried out by Professor Phelps, by the experts of the Ohio State Board of Health, by the Sewerage Commission of New Jersey and by the Department of Agriculture will, no doubt, lead to important further progress.

Even as the matter stands to-day, the engineer can furnish a community with any result in sewage purification for which it is prepared to pay. With sand filters, a clear and bacterially highly purified effluent may be obtained. With trickling beds, organic stability may be effected at less expense, and chemical disinfection will take care of the bacteria if that end be specifically desired.

---

* Rideal: *Journal Royal Sanitary Institute*, XXVI, 378.

† *Technology Quarterly*, XIX, 382.

Dr. Channing, the brother of the famous Unitarian divine, when he was once by mistake asked to conduct a religious service replied, "Oh, you have the wrong man. It's my brother who preaches. I practice." The municipalities of the United States have now every facility for imitating Dr. Channing in the field of sanitation. Methods of water and sewage purification will be improved with every year, but good practical methods are now available, and the main thing is to apply them.

[Note.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the Journal.]

THE USE OF SMALL PUMPING PLANTS IN CONNECTION WITH SEWERAGE SYSTEMS.

DESCRIPTION OF NEWTON SEWERAGE PUMPING PLANT.

By Irving T. Farnham, Member of the Boston Society of Civil Engineers.

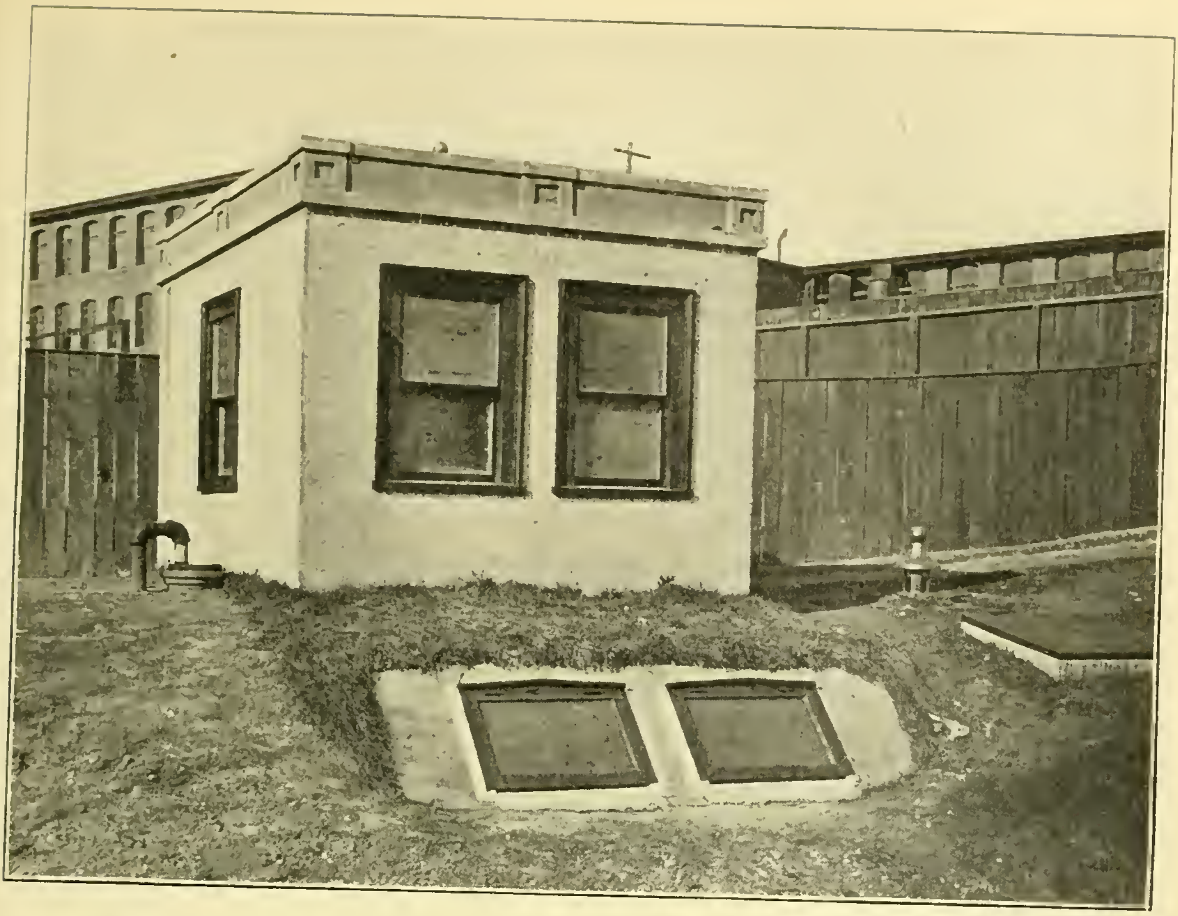
[Read before the Sanitary Section of the Society, January 9, 1907.]

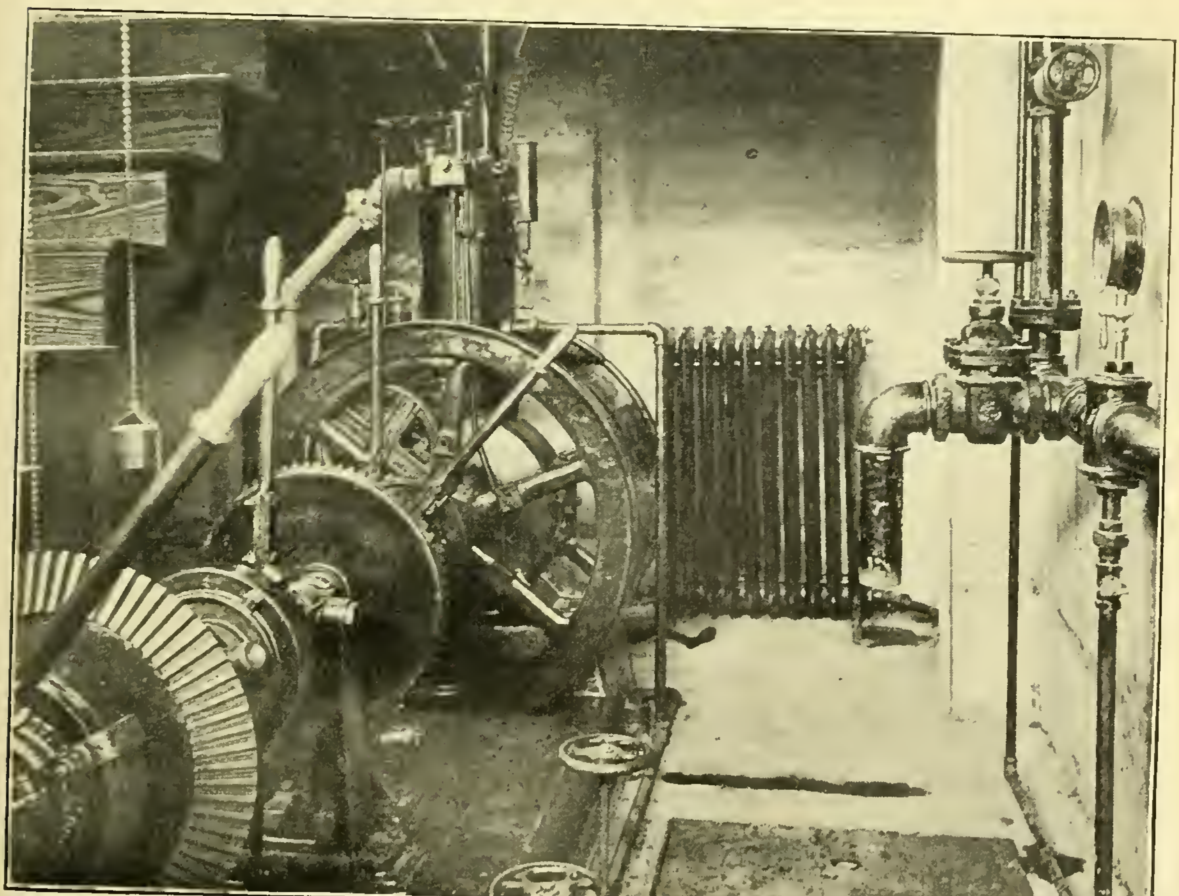
The Newton sewer system will eventually be entirely a gravity system, but the demand for sewers in a small section at Newton Upper Falls made it necessary either to construct a long and expensive line of trunk sewer or to pump the sewage up to a sewer already built. It seemed desirable to save interest charges by delaying the construction of the main until such time as the population on the area which it is ultimately to serve made this construction necessary, and the temporary expedient of introducing a pumping system was resorted to in 1903.

The topographical conditions were such that the plant could be located on land owned by the city near the water works pumping station, and at a point where the sewage can ultimately be intercepted by the trunk sewer. The area served is 22 acres, containing 30 houses, with an estimated population of 160, and the Saco & Pettee Machine Works, which employs about 600 hands.

The collecting system consists of 2 640 ft. of 8 in. vitrified deep and wide socket pipe laid with cement joints. The sewage is discharged into a circular concrete well 18 ft. in diameter and 6 ft. deep, which is divided diametrically into two chambers by a vertical partition provided with a gate. By stop planks the sewage may be diverted to either section, thus allowing the cleaning of one section or repairs to pump while sewage is discharging into the other. The sewage, before entering the well, passes through basket screens of wire woven 1 in. mesh.

Above the pump well, but below the surface of the ground, was constructed the engine chamber, 9 ft. by 17 ft. inside measurement, and above the ground is a concrete house, 9 ft. by 11 ft. inside measurements, which provides light and ventilation and affords an entrance to the engine chamber. The pumping machinery is in duplicate and consists of two 3½-in. submerged





Newton Sewerage Pumping Plant.

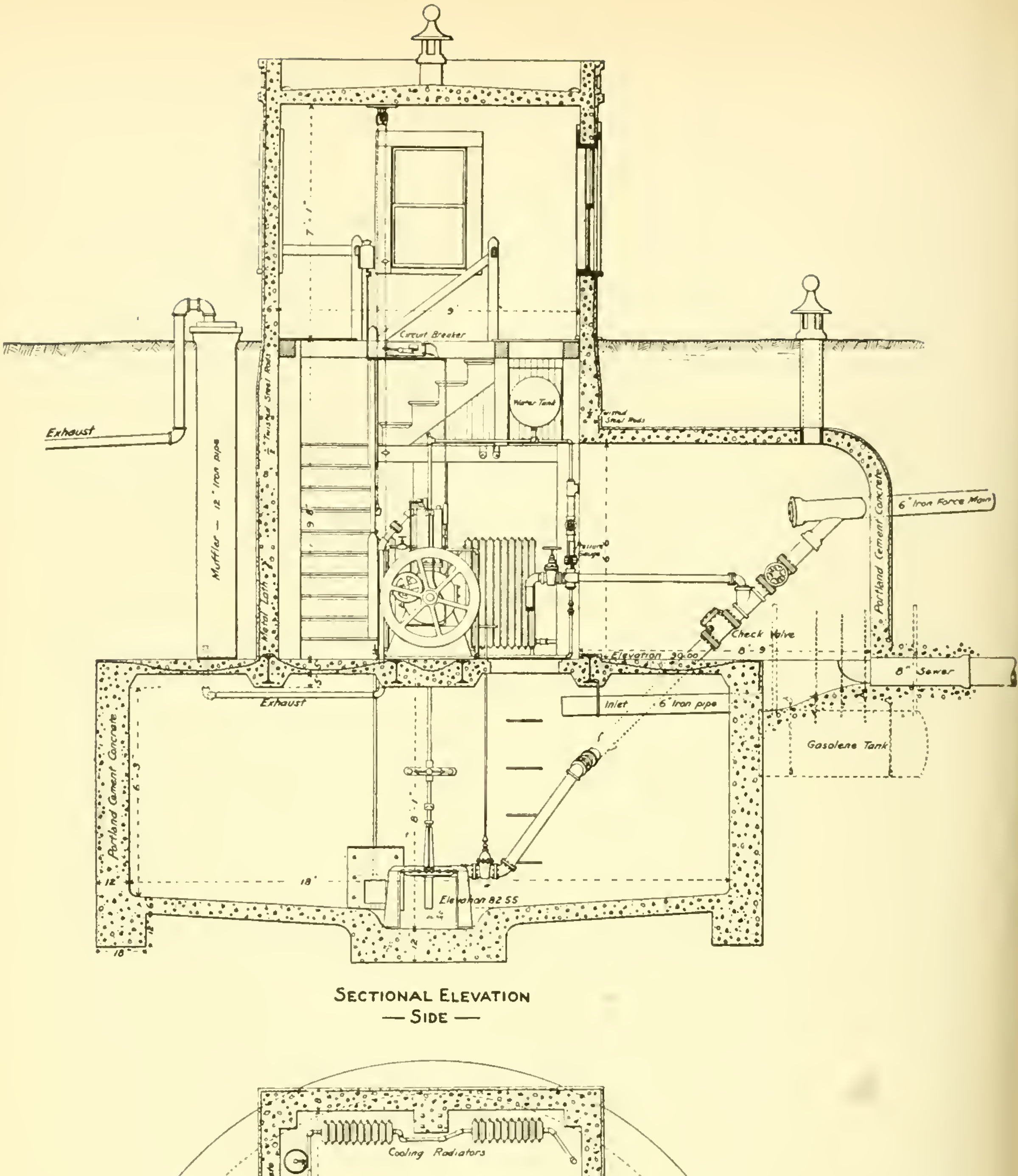
centrifugal pumps mounted on vertical axes and operated by two 6 h.p. vertical gasoline engines, which are connected with a horizontal shaft geared by bevel gears on to the vertical shafts of the pumps. By means of friction clutches on the engine shaft either engine can be used to operate either pump, both engines to operate one pump or both pumps running together. This provides great flexibility of operation and has prevented any delays in pumping when either pump or engine has needed repair or is otherwise out of service. The pumps discharge the sewage through a 6-in. iron force main, 1 430 ft. long with a maximum lift of 30.7 ft. A check valve upon the discharge pipe prevents the back flow of sewage from the force main into the well after the pumps are stopped.

The contract for the installation of machinery, made with the Charles J. Jager Company, required the delivery of 150 gal. of sewage per minute. Tests made after the pumps had been in operation a short time showed a discharge of 210 gal. per minute, and the pumps under daily working conditions are exceeding the rated capacity. The discharge main was laid at the side of the sewer trench near the surface. At each sewer manhole a special casting provides a means for opening the force main for inspection and cleaning, but during the three and a half years which the pumps have been in operation there has been no necessity for such opening. The discharge through it now is apparently as free as when it was first put in service.

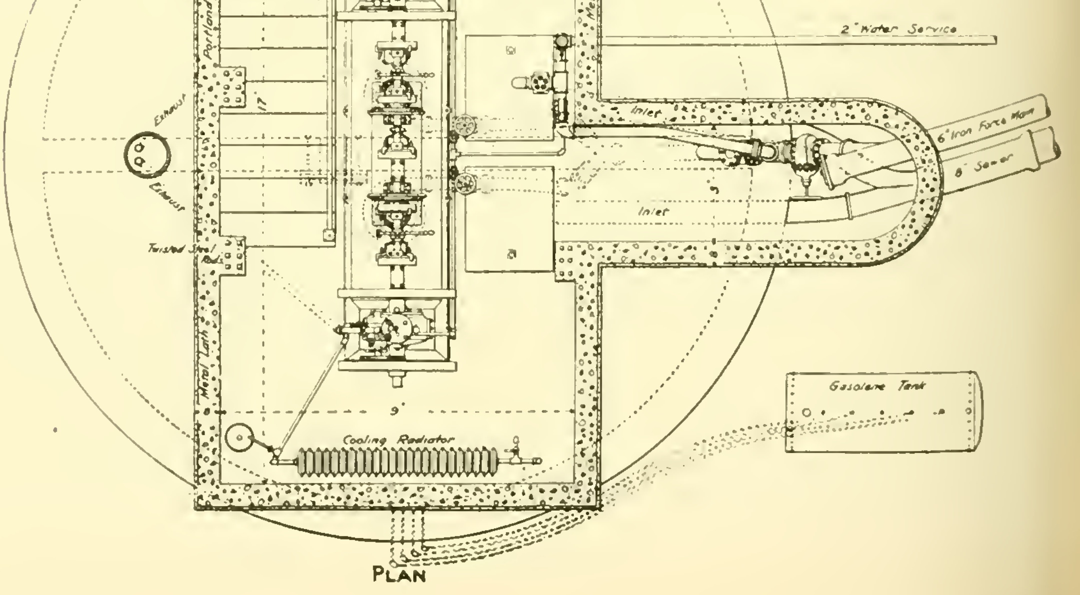
Operation.

The pump, being near the water works pumping station, is operated by one of the firemen, who goes to the plant two or three times daily, and starts one pump. A Winslow recording gage, electrically operated at the water works pumping station, indicates the amount of sewage in the collecting well and also keeps an accurate record of the flow of sewage and operation of the pumps. The attendant, after starting the pumps, returns to his work at the water works station, and when the sewage is discharged an automatic float cuts off the electric igniter and stops the pump. One of the laborers from the flushing gang goes to the plant one day each week, cleans out the screens, flushes the sludge by means of brushes to the center of the pump well, so that it may be pumped through the main, and gives the plant a general slicking up.

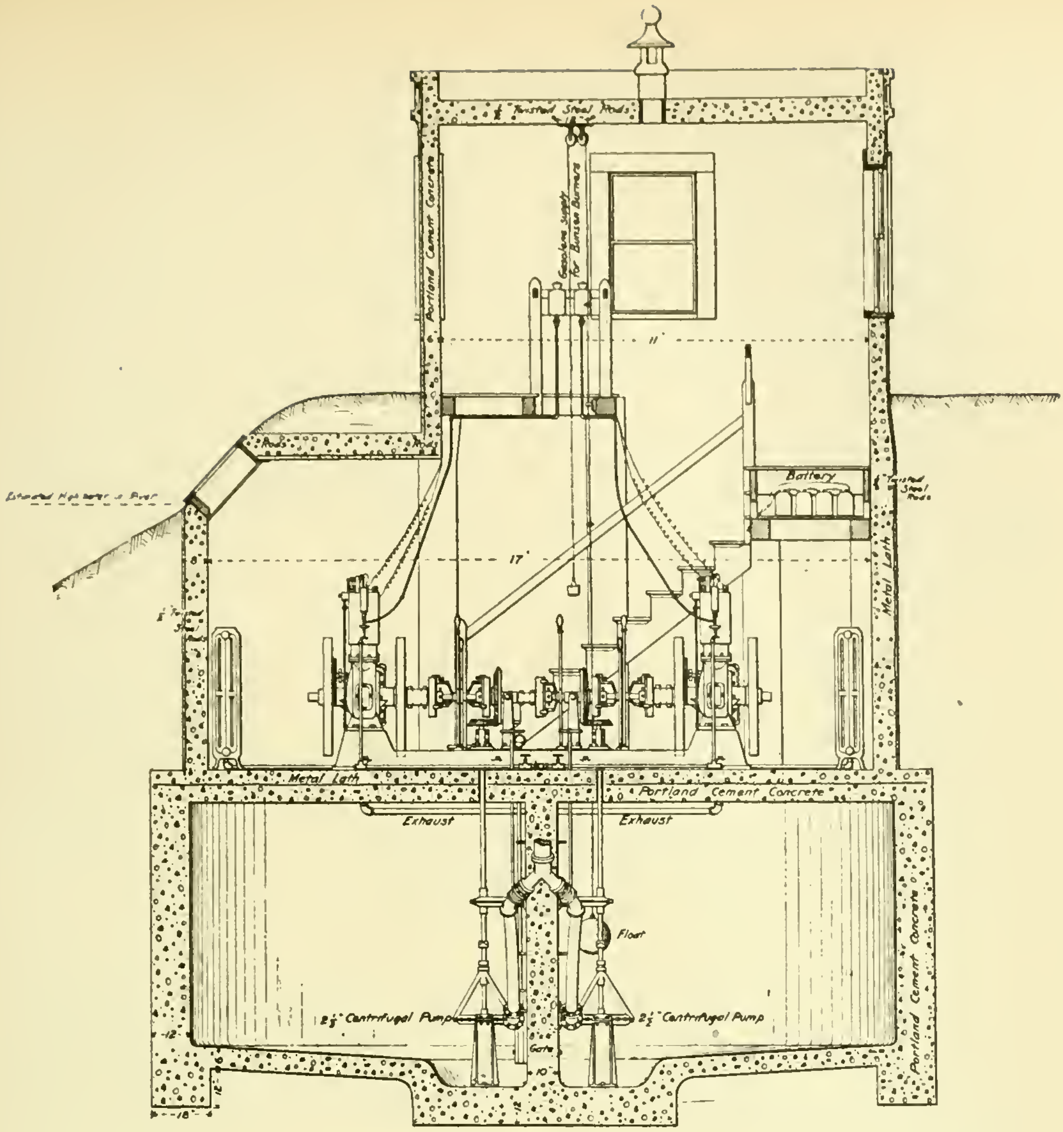
From an analysis of the daily charts made by the automatic recording gage the following facts are obtained:



SECTIONAL ELEVATION
— SIDE —



PLAN



SECTIONAL ELEVATION
— FRONT —

The plant handled, during the years 1905 and 1906, an average of 25 565 gal. daily. The maximum entering the sewage well on any one day was 53 700 gal. The leakage of ground water for the year 1905, as indicated by the inflow between the hours of midnight and 4 A.M., averaged 3 100 gal. per day, or 12.5 per cent. of the total sewage pumped. This is equivalent to 860 gal. per day for each 1 000 ft. of sewers and house connections. The maximum leakage in one day was 9 700 gal., at which time there was probably considerable water entering at the tops of the manhole covers.

COST.

The cost of the plant was as follows:

For sewage well and pumping station	$2 400.00
For construction of force main and connections	2 100.00
For installation of machinery	2 200.00
Total	$6 700.00

The average yearly cost of operation for the three years 1904, 1905 and 1906, has been as follows:

Labor and attendance	$108.50
Gasoline	145.85
Maintenance and repair of plant	66.00
Oil, batteries and other supplies	85.87
Total	$406.22

The results of operation for the years 1905 and 1906, tabulated in the form recommended by this Sanitary Section, are as follows:

B. Fuel for engine.
(*e*) Kind and grade............... Gasoline, 72 degrees test.
(*f*) Average cost.............................. 16c. per gal.
3. Amount of fuel consumed per year............. 1 168 gal. gasoline.
4. Total pumpage per year with allowance for slip...... 9 331 225 gal.
5. Average static head against which pump works .... 28.75 ft.
6. Average dynamic head against which pump works.......... 34.85 ft.
7. Number of gallons raised 1 ft. per gal. gasoline.............. 229 686
8. Cost of pumping figured on station expenses per million gallons raised 1 ft. (dynamic)................................ $1.35

The cost of fuel, which in this case practically represents the cost of power, was 58 cents per million gallons raised 1 ft. dynamic equals 15.5 cents per effective horse-power developed by pump and engine; assuming efficiency of $33\frac{1}{3}$ per cent. for pumps. This gives cost of 5.11 cents per horse-power developed by pump.

The plant as a whole has very satisfactorily performed the service for which it was intended, but a description of a plant of this kind would not be complete without a mention of some of the outs and difficulties encountered in its operation.

To my mind the most serious difficulty is one of human weakness rather than that of mechanical inefficiency. The burden rests upon some one to see that the well is kept pumped out, and if there is no emergency overflow any neglect in the pumping causes serious trouble. In this case, the collecting well was made small, as the plant was designed for temporary service and was so near the water works pumping station that the pumps could be started several times daily if necessary. The pump well and engine chamber being below the level of the river, no emergency overflow could be provided, and in two or three cases the sewage has risen above the level of the floor before the pumps were started.

When the plant was first put in operation no screens were provided, as Mr. Jager was quite confident that the pumps would

throw out anything that could come to them through the sewer, and he was nearly right, but there was one substance that he did not reckon on, namely, cotton waste, a large amount of which entered the sewer from the works of the Saco & Pettee Machine Works. This waste would knot up and collect around the suction pipe, and when finally drawn in would completely stop the discharge. The basket screens now intercept the waste, and this is about the only service which they perform. The mesh is very quickly filled with paper and the sewage overflows from the top so that the screens act as a settling sump to catch the waste.

Some difficulty was experienced with the current for the electric igniters, but although Bunsen burners are provided for use in case of emergency we have always been able to maintain an electric current. The difficulty seemed to be with the cut-off, which would short-circuit the batteries and run them down. This was corrected by providing a spring held with a latch, which is tripped by the float when the well is emptied, throwing the switch completely out of contact.

Other trouble was caused by the fine sand which comes in from the foundry of the machine works. This sand would be carried up through the discharge of one pump, and at the point where the two discharge pipes join would settle back against the valve of the second pump and cake in so hard that the pump would not throw it out. This difficulty was overcome by a little more care in the cleaning and flushing, water being flushed back through the pumps occasionally with the pressure of the water main. I believe that these are all the troubles which we have had.

The cost of operation has increased somewhat each year, due to the increase in the cost of gasoline, the increase in the amount of sewage handled and the increase in the amount of attention which is given to the pump for the purpose of avoiding the difficulties above mentioned.

DISCUSSION.

Mr. Frank A. Barbour. — The necessity of reaching elevations sufficient for the installation of disposal plants, or the economy of treating a system of interception sectionally, either because of intervening high land or territory generally too flat to permit of good gradients, often leads to the use of pumps in sewerage works.

In all cases the necessity for pumping must be proved, particularly to the local authorities, who have a well-grounded aversion to the adoption of anything but a gravity outflow. At the

same time it is generally advisable to pump if a better soil can be obtained for filtration, even though a fairly workable field may be reached by gravity. It also frequently pays to pump the entire sewage when a portion in any case has to be so handled, though a large part of the town may possibly be intercepted by gravity. Sometimes where a gravity outfall can be proved economical if figured on some projected curve of future population, it is cheaper to pump under present or probable immediate conditions. This is particularly true in New England towns which, as experience proves, are apt to develop a very hesitating growth after reaching a certain point.

The great argument against pumping in the case of small installations has been the labor charge; this is particularly true when economy in the design of a system of interception dictates the division of the area into districts and multiple pumping. With steam pumping, local attendance at each station is required and a storage capacity limiting the pump run to certain hours is a necessary adjunct. To localize the labor at one point, compressed air, under the Shone system, is of considerable value, but is generally applicable to a limited zone of distribution and from the speaker's experience of the few plants he has examined is not economical.

The more nearly continuously a pumping plant can be made to operate at a uniform rate, the more economical is the result, provided the labor account does not offset the saving in the decreased storage capacity, lessened size of force main and reduced friction head thus made possible. With a steam plant a reservoir large enough to hold the sewage during the hours the pumps are not running and a force main adapted to the pump rate are required. If the amount of sewage to be handled could be accurately predicted and a pumping unit with a capacity equal to the average daily discharge adopted, then a reservoir only large enough to equalize the hourly variation would be necessary. This cannot practically be done and the nearest approach to uniform discharge is obtained by dividing the plant into such a number of units as will most nearly approximate in their capacity the rate of inflow; in other words, by dividing the total power into units best capable of handling the load curve. With such an arrangement the reservoir can be reduced to a size only sufficient to prevent too frequent starting and stopping of the units, and the force main can be designed on the basis of the maximum rate of inflow for the period in the future which it is economical to consider. This continuous discharge is often extremely desirable

in disposal work where either purification is effected or the sewage disposed of by dilution.

Such frequent starting and stopping practically necessitates automatic arrangements, and for this electric power is apparently the best adapted. Experience has proved the possibility of operating such plants with practically no attendance except for oiling and examination of switches. It is well to call attention to the fact that no apparatus with moving parts will operate indefinitely without some care, and the inherent danger in the use of automatic pumping installations is the tendency to altogether neglect such plants. This human weakness, however, is no argument against their adoption under intelligent management.

The plant at Saratoga, N. Y., is of the type above described, consisting of 3 units of 20 h. p. induction motors, directly connected by vertical shafts to three 6-in. centrifugal pumps, the pumps being submerged in 3 separate wells, with floats in these wells so arranged as to start and stop the motors by the rise and fall of the sewage. The capacity of each unit is 1 500 gal. per minute with one pump working against a head of 28 ft.; 1 200 gal. per minute with two pumps working against a head of 38 ft., and 1 000 gal. per minute with all three pumps against a head of 42 ft. The combined efficiency of pumps and motors was, by test, proved to be about 35 per cent. The capacity of pump well is 10 000 gal., or only sufficient to balance the operation of the machinery. The amount of sewage handled daily varies from 1 500 000 to 3 000 000 gal. The cost of the plant was $5 400, including pumps, motors, automatic starting apparatus and all interior piping and valves.

At Hudson, Mass., two 15 h.p. induction motors, using a three-phase current of 60-cycle frequency, directly connected by vertical shaft to 5-in. centrifugal pumps, serve to lift the sewage to the elevation of the disposal plant. The current is obtained from the municipal electric plant at a primary voltage of 1 080, which is stepped down by static transformers to 500 volts at the motors. The pumps in this case are set in dry wells at an elevation below the height to which the liquid rises in the adjoining sewage well, with suctions laid through the concrete dividing wall into this collecting well, while the pumps are, therefore, dry and accessible for use, ready primed with each rise of the sewage in the collecting well. The normal capacity of the pumps is 500 gal. each when two units are working against a total head of 35 ft. A combined efficiency of 42 per cent. was guaranteed, and by test this was slightly exceeded.

Wherever vertical shafts are used the division of the moving parts of motor and the impeller thrust by a slip coupling seems to be desirable. The thrust bearing for the vertical shaft is an important element in the design. At Saratoga, where a bearing of several inches diameter, with alternate loose rings of brass and steel submerged in oil was employed, considerable trouble was encountered because of heating. At Hudson, a regular marine propeller bearing, with an oil-collecting pan and the oil lifted and circulated by centrifugal force, as is done in motor work, was used with entire success.

As stated above, in Hudson the pumps were placed in dry wells to make inspection easier than when directly submerged as at Saratoga. This arrangement has emphasized the necessity for particular care in obtaining a tight pump-casing so as to prevent the entrance of air into the pumps.

In both the Saratoga and Hudson installations time limit relays have been installed, which automatically cut out the current in case of stoppage of the motors or burning of the switches. The floats are so set that the first pump starts with the sewage at a certain level, and if the inflow is greater than the capacity of this pump the sewage rises to the level where it operates the float governing the second pump. This second pump, coupled to an alternating motor, runs at constant speed and, starting against a closed check with no discharge, develops the necessary pressure to lift the check and begin pumping. Where power is drawn from a lighting circuit the starting torque of motor may dip the lights for a fraction of a second unless special apparatus is inserted in the line to prevent this action. Alternate motors, started and stopped automatically, cannot be varied in speed with success. With a certain frequency and number of poles a fixed number of revolutions per minute results. The variable factor in obtaining the desired pump capacity is in the radius of the impeller. Motors with a multiple number of poles can, however, be obtained, the number being changed by the attendant so as to change the speed in the inverse ratio to the poles in use. With direct current the series parallel method of control can be utilized to automatically vary the speed in such a way as to adapt discharge to inflow within certain limits. Where direct current is used the motors cannot be safely subjected to the same overload as with alternating motors, and in order to prevent comminator difficulties under the torque, developed in starting centrifugal pumps, large relative motor capacity must be provided.

The cost of the Hudson plant was $3 600 complete, including motors, pumps and all interior piping and electrical apparatus.

At Fredericton, N. B., an electrical plant, consisting of two 15 h.p. motors, directly connected by vertical shafts to two 5-in. centrifugal pumps, is being installed to pump the sewage during such period as the river is above the elevation of the outlet of the sewer. This plant, utilizing a three-phase alternate current, is necessarily designed to give a circumferential speed of impeller sufficient to discharge the desired amount per minute — 500 gal. — against the maximum height of water in the river. This height varies 20 ft. and, with the short length of force main, is the governing factor in determining load. In this case, however, with constant circumferential speed, it is found that the maximum load on the motor occurs not with the maximum head but with a lower head. This because of the fact that in the case of a centrifugal pump the discharge increases in greater inverse ratio than the reducing head, and the maximum load occurs at some intermediate point between the maximum and minimum head, the exact place of which depends upon what may be called the characteristic of the pump and this upon the curve given the impeller. Each centrifugal pump has its own characteristic and a breaking-down point beyond which discharge will not increase beyond the inverse ratio of the head. This is a phase of the problem which must be taken into account wherever the head is liable to change either because of a varying difference between source of supply and point of discharge or in the case of a force main which may empty because of reduced friction head at the time of starting the pumps. Unless care is taken in the selection of the impeller curve it is possible, under reduced head, to bring such a load on the motor as to burn out the windings.

The cost of the Fredericton plant was $4 000, including the motors, pumping, piping, time limit relays and automatic starting and stopping apparatus. This is equivalent to about $3 000 in New England. The guaranteed efficiency is 52 per cent. and there is a proviso in the specifications that for each 1 per cent. difference between the guaranty and that actually obtained by test, a penalty of $50 will be imposed or bonus paid. In this connection it should be noted that high efficiency in handling sewage sometimes increases the tendency to clogging of the pumps because of the decreased impeller clearance necessary to this efficiency, and it is sometimes better in sewage work to adopt a pump with lower economy or one requiring less screening of the sewage.

One of the advantages of electrical pumping is the possibility

of placing the apparatus below the ground surface and without any building. At Atlantic City, because of the flat character of the country and the small elevation of the streets above tidal level, several pumping stations are to be installed. These are to be placed below the streets or sidewalk, the stations being lighted through the roof with glass sidewalk lights. The screens will be raised by hydraulic lift above the elevation of the ground and there cleaned in a manner similar to the old sidewalk elevator.

At West Chester, Pa., the peculiar topography of the city renders absolutely impossible the collection of the sewage at one point, making it necessary to install two pumping stations. These will be similar to the units at Hudson and Saratoga, but in this case single-phase current will be used. The difficulty with such current has been the overcoming of the starting torque, but in small motors this can now be done.

In any case the use of gasoline or oil engines, gas producers, steam or electricity must depend altogether on local conditions. Where a number of small plants are to be installed, widely distributed in location, and where current can be obtained at a reasonable cost, the automatic possibility of electric operation will usually render this the most economical and advisable. In the case of Saratoga, where power is obtained from the Spier's Falls Plant on the Hudson, there is no doubt that in actual cost of power this plant is far more economical than would be possible under any other method. In the case of Hudson, where the current is obtained from the municipal plant, the actual charge is between different departments of the town and is largely one of book-keeping. It is to be noted that the use of electric current, with the greatest demand during the hours when the amount of light required is at a minimum, serves to smooth out the load line, and it is probable that 2 or 3 cents per kilowatt hour is as high as can reasonably be put down as the actual cost. In such cases electricity will compare favorably in point of cost with any other form of motor. The possibility of small artistic stations, odorless and noiseless, without chimney or exhaust pipe, is a feature to be counted in favor of electric pumping, particularly in summer resorts or high-class residential districts, where the absence of obtrusive evidence of the object of the building is important. Pumping is sometimes thus made possible where steam or gas engine plants would not be tolerated.

The use of heavy oil engines is suggested by the rising cost of gasoline, and in Canada, where the price of the latter makes its use practically prohibitive, it is the only form of oil engine

which can reasonably be considered from a municipal standpoint. In connection with such type of motors, the best method of attachment between motors and pumps is an interesting phase of the problem. Gearing is usually noisy, and while this undesirable factor can be reduced by the use of rawhide gears, no such plant can be compared in smooth working with a steam engine or directly connected centrifugal pump. In hitching up engines with centrifugal pumps the use of silent chains is worthy of consideration. With a guaranteed efficiency of 98 per cent. and the short distance between centers, this method has features in its favor beyond the old belt, the only offsetting condition being the high price charged for these chains.

In the past year there appears to be a growing appreciation of gas-producer plants. Such plants, while demanding little attention, do not permit of automatic operation. In point of economy, however, they apparently offer inducements greater than that possibly obtainable under any other method. With the plant now being installed at St. Stephen, N. B., a guaranteed duty of 115 000 00 ft.-lb. per 100 lb. of coal is specified, this to include all standby losses, with the pumps actually operated 8 hours per day and banked 16 hours. In this connection the small consumption of fuel used during banking in a producer is an important consideration.

Mr. C. O. Rogers. — Gentlemen, I want to thank you for the opportunity of being present. I did not attempt to prepare any formal paper, as I did not expect to be called upon quite that way. One or two points occurred to me, however, in listening to Mr. Farnham and Mr. Barbour. I was quite intimately concerned in the design and erection of the plant at Newton Upper Falls and have felt interested in that plant from the time of its starting to the present time.

I am glad to notice the fuel observations which Mr. Farnham brings to our attention, and in that connection I want to say that the fuel which we should expect that engine to consume in the case of a test of any duration that we cared to give it, under expert handling and proper adjustment, would probably be one sixth of a gallon per horse-power per hour, or possibly somewhat better. Mr. Farnham's results for the entire year show a consumption of only a little better than one third of a gallon per horse-power per hour. Possibly this undue difference may be traceable to the difference between expert handling of the engines and the comparatively inexpert handling which Mr. Farnham's operator gives them.

In plants of that size and smaller, with several of which I have been connected, it seems to me that it is wiser to look for reliability in the operation of the machinery rather than for an extreme of economy in fuel. The incidental expense due to flooding of the sewage basin, or due to failure to start the machinery on the part of the attendant, is much more important than the consuming of a gallon or two of fuel more in the day's run. This point of not looking for the highest possible efficiency relates both to engine and pump. In the design of a centrifugal pump, the highest possible efficiency is gained by careful adjustment of the form of the impeller, and also of the clearance between that impeller and the shell surrounding it. If the clearance is brought to the smallest point, while the efficiency of the pump is increased, the ability of the pump to pass heavy solid matter, such as is likely to come to it in the operation of a sewage plant, is greatly reduced; and under those conditions, the cost of cleaning the pump overbalances the gain in efficiency. As a consequence, in designing we are accustomed to give them undue clearance and stand the loss due to the lesser efficiency. That seems to be the wisest plan.

As regards a comparison between gasoline and electric power, it is unquestionably a matter for local selection. The conditions governing the individual plant must decide on that point. In the case of the electric motor, it is always possible, by means of undue overloading, to burn out the motor if the fuses do not protect it. In the case of the engine, it is absolutely impossible, if the engine is provided with oil at the proper points and there is water in the jacket, — it is impossible for overloading to damage the engine. It may require additional attendance to start again if overloaded to point of stopping, but does not injure the machinery itself. That is one point that has not been properly brought out.

Mr. Lewis D. Thorpe. — The use of internal combustion engines has become so general that I am afraid anything I may say will perhaps be an old story to many of you. I have also had very little time to look up and prepare notes, but will try to give a brief description of a sewage pumping plant designed by the late Freeman C. Coffin for the city of Charlottetown, P. E. I.

The plant was constructed during the seasons of 1898 to 1900 and has been in continuous use ever since. The sewage from a portion of the city is discharged by gravity, but there are two sections, one on each side of the gravity section, whose sewage has to be pumped to points on the gravity line. It is then

discharged out of the main outlet. Two pumping stations were built, one for each section. The west section is composed of about 5.5 miles of from 6-in. to 12-in. sewers, and the force main is 10-in. cast-iron pipe 800 ft. long. The east section has about 3 miles of the same sizes, and the force main is 10-in. and 940 ft. long. The west reservoir has a total capacity of 75 000 gal., and the east reservoir, 65 000 gal. Each station is provided with a 7 h.p. horizontal Otto gas engine, and one 3-in. and one 4-in. submerged centrifugal pump, which are driven by belts from the main shaft on the engine, the shaft being connected to the engine by a friction clutch. By a simple float arrangement the engines are arranged to stop when the reservoir is emptied, and at the same time to cut off the supply of cooling water and, by opening a cock, drain the jacket of the engine. The cooling water is taken directly from the city mains. Each engine is also provided with a gasoline attachment that can be placed in position in a short time and gasoline used in place of gas. A Winslow recording gage connected to each station is located in the office of the sewerage commissioners. These gages indicate the height of sewage in the reservoirs at all times. The height is also recorded on charts. These charts give a continuous record of the height of sewage in the reservoirs, and also the date of pumping. Several brake tests were made with the engine at the west station under varying loads for the consumption of gas per horse-power. The following are some of the results obtained:

1.12 h.p.	gas used, 59 cu. ft. per horse-power hour.
2.23 h.p.	gas used, 39 cu. ft. per horse-power hour.
3.33 h.p.	gas used, 30.6 cu. ft. per horse-power hour.
5 h.p.	gas used, 24.6 cu. ft. per horse-power hour.
7.52 h.p.	gas used, 23.2 cu. ft. per horse-power hour.

Repeated tests were made and the results were in each case about the same as the above. Several pumping tests were also made at the west station with practically the same results in each case. During a two-hour run, made with the 4-in. pump, 71 230 gal. of sewage were pumped, or 594 gal. a minute, against a total head of 30.76 ft., the engine running at 280 rev. per min. and the pump at 685 revolutions. The total amount of gas used for this run, 345 cu. ft., would be at the rate of 4 843 cu. ft. per million gallons pumped. This at $1.25 per thousand cubic feet would cost $6.05 per million gallons, or 20 cents per million gallons pumped 1 ft. high. The work done as measured by the sewage pumped was 4.62 h.p., or 61.7 per cent. efficiency.

A test was also made of the 3-in. pump with the follow-

ing results: Length of run, 2 hr.; speed of engine, 304 revolutions; speed of pump, 795 revolutions; the total amount pumped, 52 200 gal., or 435 gal. per minute, against a total head of 28.35 ft. The gas used during this test was 351 cu. ft., or at the rate of 6 725 cu. ft. per million gallons. This, at a cost of $1.25 per thousand cubic feet, as was paid in Charlottetown at that time, would be $8.40 per million gallons. The amount of work done, as measured by the sewage pumped, was in this case 3.12 h.p., or about 41.8 per cent. efficiency.

The pumping plants are very simple to operate and require very little attention. I have repeatedly started the engine and gone away leaving it to take care of itself, not going near it again until it was necessary to pump the reservoir out, and never found any trouble. It usually took about 20 minutes to oil the engine and bearings and get it to going smoothly.

The total cost of the pumping machinery erected was about $1 400 for each station. This does not include the cost of recording gages.

Mr. F. H. Hayes. — I do not know that I have very much to say in addition to what has already been said about handling sewage by centrifugal pumps, not having had as much experience with these pumps as with the double-acting piston pumps. At Pittsfield, Mass., we have our largest installation of the double-acting piston pump. This is a triplex, horizontal, electrically-driven pump; it handles 3 500 gal. per minute, and delivers this amount of sewage through 2 400 ft. of 24-in. pipe upon specially prepared beds. The electric current is furnished to the city by a local company, for an 8 hr. day-time run, at a very reasonable price, and if a longer run is required, owing to any emergency, there is an additional charge therefor. The plant has been in operation for five years and we have lately had the pleasure of receiving an order for an 8 000 000 gal. triplex sewage pump to go alongside the first one.

The 50-ft. head against which the Pittsfield pump works is practically the same as the heads named for the centrifugal pumps of which you have heard to-day; but when the two styles of pumps are working under the same conditions we claim the greater efficiencies are with the piston pump, and also that the degree of efficiency will be much longer retained by the piston pump.

In the matter of first cost, the odds are greatly in favor of the centrifugal pump. But when the purchase of a sewage pump is being considered, not only must the first cost be taken into

account, but the amount of sewage to be handled, the disposal which is to be made of it and the suction lift.

You will see that on the whole it really comes back to a matter of arithmetic, with this exception: If the centrifugal pump refuses to operate when power is applied, it is as a submerged pump difficult to inspect, and, unfortunately, it has been our experience that submerged pumps are most wanted in times of emergency and most apt to be inoperative at such times. If a piston pump becomes inoperative it certainly has the merit of being where it can be easily gotten at, and therefore is more readily inspected and kept in repair.

We are now getting ready to install at Framingham, Mass., an electrically-driven duplex piston pump to go alongside of steam pumps which have been there for nineteen years. I think the cost of running the electrically-driven pump and the steam pumps will be watched with a great deal of interest, the experiment never before having been tried under such good conditions for determining these data.

When bids were called for on this Framingham machine we were asked for steam-driven machines and given the privilege of making prices on power machines driven either by gas-producer engines or any of the internal combustion engines. When bids were first called for, an electrically-driven pump was not to be considered owing to the high price charged for the electric current by the Edison Company. Later an acceptable proposition was received from the Edison Company for the electric current, and the bids for an electrically-driven power pump were entertained. The pump we are preparing to install has a capacity of 2 000 000 gal. in 10 hr., and the run is to be made in the daytime when the Edison engines are underloaded.

You will note that the Framingham and Pittsfield pumps are similar except that the Pittsfield pump is triplex while the Framingham pump is duplex. Both pumps are fitted with clapper valves allowing free passage for the sewage material. We have been asked to put in vertical triplex pumps with ball valves, and have installed some in small sewage stations, where they are doing good work.

One of the great troubles which comes to all sewage pumps is the result of incorrect screening, and we learned this very early in our Pittsfield experience, for the first screens were so coarse that they allowed the passage of cotton waste, towels, stones, etc., to the pump. After clearing the pump valves, new and finer screens were put in place and the trouble has not arisen since.

The hardest thing to prevent from reaching the pump is cotton waste.

Mr. Johnson. — I think Mr. Hayes can give us some interesting information about trouble experienced with the gearing at Pittsfield.

Mr. Hayes. — In regard to the gearing at Pittsfield, when it was put in we did entirely as we were called upon to do. We furnished a double-geared pump and the inter-gearing had wood teeth. The pump when started was very noisy and could be heard for a long distance and the inter-gears would not hold, going to pieces rapidly. As a consequence we changed from direct connection to belt drive. The pump which you would see in Pittsfield to-day is entirely belt-driven, and from this experience, wherever we can, when considering power installations, we insist on belt connections instead of direct connections. If, however, direct connections must be furnished, the noise can be somewhat lessened by the use of rawhide pinions.

In Pittsfield, owing to the changed mode of connections between pump and power, we had to use two belts. We would recommend, however, wherever possible, the use of one wide belt, The excessive cost of the silent chains prevents their common use on electrically-driven pumps. We have used some of them with good success. We have one at Gardiner, Me.; it is not, however, on a sewage pump.

In all cases where I am asked for advice about how a power pump shall be driven, I say, Belt it.

A Member. — I want to ask Mr. Hayes what he would use in the case of a triplex electrically-driven machine.

Mr. Hayes. — I should use the belt. It is to be demonstrated in the coming week at Dover. Excuse me for mentioning these things; they are the installations I know of, and so speak of them. At the time these bids were called for, we were asked to make prices on double reduction gears, and we told them the noise of such gears would be obnoxious to their people, with the result that a belted pump was ordered. This Dover pump is electrically-driven belt-connected vertical, and has a capacity of 2 500 000 gal.

There is another point I would like to call to the attention of the gentlemen present. Many times when we are asked to make prices on electrically-driven pumps and motors we are asked, " How long can we leave them alone when running? " Some people would like to leave them alone for 24 hr. But so far as our experience goes it is not good judgment to do so. A

plant that will cost from $2 000 to $5 000 requires and is worthy of some care, and it should be seen as often as every 3 or 4 hr. At least this is my judgment, and it is the advice I give in answer to the above question. I know of places, where our pumps are running in connection with oil engines, where they are shut up at night and left to run until morning, and so far no trouble has ever resulted. But if trouble came to them, the resulting cost might be a good deal more than the little money required to give them a reasonable amount of care during the night.

Mr. F. L. Fuller. — I have had experience with two pumps of this kind, both direct connected. The noise was excessive, which is largely unavoidable under such conditions. At Franklin. N. H., even with a rawhide pinion, it is difficult for two people to converse with any satisfaction. The pump is an 8- by 10-in. triplex, electrically-driven, and is located in a concrete building or pumping station 22 ft. long by 20 ft. wide. At Uxbridge, Mass., an 8.25- by 10-in. triplex pump, also electrically-driven, is located in a stone and brick pumping station 24 ft. long by 22 ft. wide. This plant is not as noisy as the previous one. It would seem improbable that the difference in the material's of which the buildings are constructed should affect the amount of noise produced in running the machinery, although it is, of course, not impossible.

Mr. Farnham. — On the subject of gears. That part of the Newton plant gave me some uneasiness, because I knew they had not been entirely satisfactory in other places. However, Mr. Rogers worked the problem out and assured me he could put in gears that would not be noisy and would give satisfaction. And I will say that they have been entirely satisfactory. There is very little noise from them. The engine chamber is small, and, having masonry walls, sounds resound considerably, so that while you are in the pumping chamber you hear considerable noise, but a little distance away you can't hear it at all. The plant is within 40 ft. of the street and I hardly think that you'd know the plant was running unless you listened for the puff of the engine. Perhaps Mr. Rogers will tell us more about the gears.

Mr. Rogers. — When we have the problem before us of driving the shaft of a submerged centrifugal pump from the horizontal shaft of the engine, one of the prime requisites is that the drive shall be positive. The plant may be left for a considerable time without attendance and the connection between power and pump should not be lost. The gear drive, of course, answers that difficulty beyond all doubt so long as it is properly designed

and strong enough to drive without breakage. In regard to the Newton Upper Falls gears, they are of bronze and cast steel working together, and are planed bevel gears with ample face. We find that in adding to the face of the gear within reasonable limitations we reduce the amount of noise connected with it. We have also found, in one or two other instances, as well as at Newton, that the noise could be reduced by breaking the continuity of the gears themselves. We have reduced the noise in a number of cases by sawing into the rim at different points in the section, so as to break up the continuity.

The first we put in of the geared type was at the sewage pumping plant for the Dana Hall School at Wellesley. I think that was put in in 1902 — a 2-h.p. gasoline engine operating a 2-in. pump with a capacity of 60 gal. per minute against 14 ft. of head at the time it was put in. There have been improvements since, so that they have had to increase the head against the pump to 25 or 26 ft. We are now delivering to the new location about 40 gal. per minute against the increased head. The gears here are also of bronze and cast steel and the pumping machinery is located inside a wood-walled pit, where we don't get the reverberation due to concrete walls, and it is not unduly noisy. It is not absolutely quiet, but it doesn't produce more than a local sound, which hardly comes out of the pump room. It is almost invariably the case that sewerage buildings are located in a place where local noise is not objectionable, and this noise is purely local. But the disadvantage produced by these local noises is more than balanced by the positive drive.

Mr. Hayes. — Might that not be overcome in a general way by using the wood-tooth gears?

Mr. Rogers. — The gears are hardly large enough to permit of the mortised tooth. The larger gear is about 16 in. in diameter and something like a 4 pitch. It is too small to attempt to use the mortised tooth.

Mr. Weston. — Doesn't the length of the shaft the gears are on have something to do with the noises?

Mr. Rogers. — If the shaft is rigidly supported, I can hardly see how that can have any effect. If the shaft is permitted to vibrate while running, it would, of course, have a great effect.

Mr. Leonard Metcalf. — In connection with the chain-drive, it may be interesting to give an account of a plant I saw this summer, which was installed in a theater in Chicago by the Allis-Chalmers Company. They showed me their triplex pumps,

which are driven by the noiseless chain. The engineer told me that they had been in use about four years and had never given him any trouble.

Mr. Weston. — I should like to ask Mr. Rogers what his opinion is as to the position which the end of the suction pipe should occupy with reference to the bottom of the pit.

Mr. Rogers. — My conclusion was that it should be placed near the bottom, so that the pumps should be as near to the sewage proper as possible, and so that the pipe line should be just as short as possible. Mr. Farnham spoke of the workmen going in every week and stirring the bottom up. I think that is very essential.

Mr. Weston. — Then you would place the end of the suction pipe as low as possible in the pit?

Mr. Rogers. — Yes. At the risk of making the Newton Upper Falls plant an unwelcome visitor, I want to speak about the heating of the station. The pump room containing the engines is below the ground about 8 ft. The gasoline engines used there for power naturally generate heat and require water in their cylinder jackets to keep them cool. In developing the cooling system in that plant a suggestion came to us to use a system of radiators around the walls of the room, circulating the water through the engine jacket and then through the radiators and overhead expansion tank and thence back to the engine jackets. The location of the engine room and this circulation water supply system, with the necessary starting of the system about three times a day, every day, just about supplies the heat necessary to keep that plant secure against freezing. Mr. Ross tells me there has never been any difficulty of this kind in that station.

A Member. — Did you ever use oil in these stations?

Mr. Rogers. — We use water. We have used oil, but the cost of leakage on it would make it undesirable. The radiators themselves are exposed in this room, and there never has been any question about freezing. Probably the winter before last was about as severe a winter as is likely to come, and they stood that test.

Mr. Metcalf. — There is one further question I would like to ask Mr. Farnham, Mr. Rogers and others who have had experience, and that is as to what they consider the practical limit in size of the centrifugal pump which can be used in pumping sewage. In this example at Newton Upper Falls which has been brought to our attention they are using so small a pump

as 2.5 in. I have always been afraid of these very small centrifugal pumps for this sort of service, and I am surprised that they have had no more trouble with clogging of the pump than is reported. The designing of screens for a plant of this kind which will satisfactorily care for the waste which gets into our sewers is troublesome and difficult. My own experience with the basket screen has been very unfavorable. The only satisfactory screen I have had anything to do with has been one made of slats and not a basket weave. Even the slats are not altogether satisfactory, because, as many of you have doubtless noticed, a rag or a towel will go up against the screen, flap there for a little while, gradually weave itself into a little tight roll and slip through the screen with an opening of anything over three fourths of an inch. I have seen them go through the screen and clog the pump several times. In the case of the larger centrifugal pumps, of course, such substances will readily pass through. But I wonder at these works not having trouble with as small a pump as 2.5 in.

Mr. Farnham. — I presume that Mr. Rogers can give more information about the smallest size than I can. I believe there are smaller pumps than ours in use. I haven't any hesitation in saying of the 2.5-in. pump that it has done the work splendidly. The only trouble we had was with waste, and this before we put the screens in and before we knew we were going to get so much. The only way I can explain the satisfactory operation of the basket screen is, that the waste being heavier, undoubtedly settles down and collects in the basket, so that the basket acts as a sump for collecting a large part of the waste. The mesh is very soon stopped up with paper and sewage overflows from the tops, but the pump throws all other substances out. The trouble from sand occurred only once or twice and was probably due to lack of care in management. That trouble had not developed and we did not operate to prevent it. Had we operated two pumps alternately, probably the sand would not have caked in hard enough to make trouble. It pumped up through one pump all right and settled back against the other pump. The sand is the kind they use for molds in the foundry and it cakes in very hard. The trouble occurred once or twice, and as soon as we discovered what it was it was remedied by a little more care in the management of the plant.

Mr. Metcalf. — Is there any trouble in cleaning out those screens?

Mr. Farnham. — I never go there. One of Mr. Ross's men

is detailed to do that work. He is a man of the flushing gang who is not afraid to get his hands dirty. He picks up the waste with a hook, the other matter is thrown into the bottom of the well, with a broom he sweeps it down toward the center of the well and the pump is started. He separates the waste from the other matter and in the course of two or three weeks collects a bushel of it.

Mr. Rogers. — I can add a word of testimony to what Mr. Farnham has said in reply to Mr. Metcalf's question. At Dana Hall they are using a 2-in. pump. The sewage handled there is from a private school and undoubtedly does not contain as much of this heavy waste matter as ordinary municipal sewage would. But the size of the pump at Dana Hall School was selected, not because that size of pump would deliver that quantity of water most efficiently, but because it was considered the smallest desirable size to attempt to use in handling that class of material. It is cheaper to add 1 h.p. to the power of operation than to have any trouble with clogging, and that is about what we have done there. In three and one-half or four years of operation I have heard of no difficulty, and I think the plant has required no undue amount of cleaning.

Mr. Bertram Brewer. — We are building now a plant at Waltham very similar to those described this evening. I don't know that I can add much to the views expressed here except to say that I was very much interested in Mr. Farnham's paper and I think it is entitled to a very careful reading because he is the man who put the plant up and he has to live in the city where it is being run, and he speaks from experience. Our plant in Waltham consists of an electrically-driven vertical motor and vertical pump. The head which we use to pump against is something like 40 ft. We have 2 units — two 5-in. pumps and two 15 h.p. motors, alternating current.

I have found in designing an isolated plant to work automatically there are many difficulties to overcome. For instance, this question of cotton waste, and the necessity for screening. In the Worcester plant, in a large main, where there is a considerable quantity of sewage, a screen was used at first but got out of order, has never been repaired and is not needed. This is not always so. In my own city of Waltham, the watch factory has pumped sewage into the mains for a good many years and has had a hard experience in evolving an automatic plant for that place; so much so that some of our aldermen, who are employed at the watch factory, did not think it was possible to pump sewage

automatically by electrical motors. The watch factory had trouble with waste and still more trouble with air in the pump at starting, owing to the fact that it was placed at the top rather than at the bottom of the well. Mr. Farnham spoke of trouble with waste and sand, and I think those are two things to be looked out for.

The pumps should be placed at the bottom of the well, in a dry pit, with the entrance to the suction pipe, which should be very short, so located that all the harder materials will be frequently stirred up and constantly removed. A long suction gives an opportunity for the harder materials to accumulate.

I have seen the Hudson plant in operation at two different times. There the pumps were placed in a pit by themselves so they could be gotten at at all times; but, when I have seen the plant, the pumps have been purposely submerged in water. I found that there was great trouble with the stuffing boxes and that the pumps leak and have always given trouble, so that the pump pit is kept full of water. Many of its advantages are thereby done away with. I don't know what steps have been taken in more recent plants to overcome this difficulty. I know in my own case it was suggested to me by the manufacturer that he cast a sleeve around these glands which will provide for submerging them alone.

Another problem is connected with the apparatus for starting the motors automatically. In Waltham we have to buy our current and expect to have a special wire in our station to serve our purposes. I have found it very hard to get a reliable automatic starting device for an automatic alternating current motor. I have investigated three: the Westinghouse starter, the Cutler Hammer and one which is manufactured by the General Electric Company. The one used in Hudson is manufactured by the last-named company. As has already been stated this evening, a circuit breaker with time limit relay to take care of an extended overloading of the motor is used in Hudson. The electrician who has charge of the plant informed me, however, that this part of the apparatus was so delicate and so easily affected by temperature changes that it was difficult to keep it in working order.

One of the essential features of the Cutler-Hammer auto-starter is the use of water under pressure from the city mains. This necessitates a warm pump house, and, in an isolated plant, a considerable item of expense. Other starters require that some of their mechanism should be immersed in oil, and as a consequence more or less heat is required to keep the oil from congealing.

There are many interesting and important details in connection with the designing of small automatic sewage pumping plants yet to be satisfactorily worked out. The more isolated the plant, the more difficult is the problem. It must be operated with intelligent care and, what is more, by one who is interested in its success.

Mr. M. N. Baker. — I should like to mention one thing that might be worthy of recollection when we develop a little further in the disposal of municipal waste, and that is this: In Great Britain there are many municipal refuse destructors operated at very high temperatures. These destructors are invariably connected with steam boilers, the steam from which is utilized for sewage or water-works pumping, or for electrical supply — sometimes lighting and sometimes electric traction. An English engineer who was talking with me only last week spoke of an installation where the heat from the refuse destructor was being used to pump sewage to an elevation of 300 ft. At a sewage pumping station at Watford, England, which I visited three years ago, steam from the destructor boilers had just been substituted for coal-raised steam. In New England, unfortunately, although much progress has been made in water supply and sewage disposal matters, there has been but little advance in the disposal of municipal refuse. Where any attempt at burning the refuse has been made the result has generally been unsatisfactory. Elsewhere in the United States more has been attempted, but the results have been about the same. I am sure that in the future we are going to see some experimental work on this line. The Borough of Richmond, New York City, now has under consideration bids for a refuse destructor of the British type from representatives of two of the leading English companies. [The contract was subsequently awarded to one of these companies.] Provision is made for the utilization of heat from the burning of mixed refuse; that is, garbage, rubbish, papers, etc., and the ashes. A report has just been made to the city of East Orange on the possibility of combining a refuse destructor with the proposed installation of a municipal electric lighting plant. Although it may be some time in the future before much is done towards utilizing heat from American refuse destructors to pump sewage, it is worth while to have the possibility under consideration. For the present, such a plan would seem to be most feasible where sewage pumping is required for a relatively small portion of a city only, thus insuring a plentiful supply of refuse to do all the pumping. Such districts, and especially the sewer outfall therefrom, are likely to be in outlying sections where

a refuse destructor would be least objectionable. Moreover, the haul of the loaded refuse carts would, in such cases, be downgrade.

Mr. Andrew J. Gavett (*by letter*). — It is proposed to install a small pumping plant at Plainfield this spring. The proposed apparatus will be furnished by the Ingersoll-Rand Company, of New York, through Warren B. Travell, whose proposal was based on the Ingersoll-Rand outfit.

The Ingersoll-Rand Company proposes to furnish and install, with the necessary foundations, the following apparatus, which will include the necessary valves to enable either pump to be cut off from the system for purposes of inspection or repair without interfering with the operation of the other pump:

Two 10 by 6 Ingersoll-Rand class " E " compressors.

Two 7.5-h.p. Wagner motors, equipped with Cutler-Hammer automatic stopping and starting device, with float switch which will operate to start and stop the compressors according to the level of sewage in the float tank.

One Fairbanks-Morse gasoline engine for operating the compressors in the event of failure of the electric current.

One 42-in. by 8-ft. air receiver.

Two duplex displacement pumps or ejectors, to be operated by air supplied by the air compressors.

The plant is guaranteed to have a capacity sufficient to handle 250 000 gal. in 16 hr. against a static head of 13 ft., through an 8-in. force main 2 500 ft. long, and when operated by electric motors to be automatic in operation, requiring only such attention as is necessary to keep the machinery properly lubricated and in working condition.

The Ingersoll-Rand Company proposes to use pneumatic displacement pumps manufactured by the Latta-Martin Pump Company, of Hickory, N. C.

The price for pumping plant as described is $4 655. This does not include the concrete operating chamber.

In the event of failure of the electric current the belt is to be transferred by hand from motor to gas engine, an electric alarm being given by the rise of the sewage above a determined point.

The proposed pumping plant will provide for one of several sections of the city lying too low to be drained by gravity to the disposal works.

The main sewer may be used as a storage reservoir up to a capacity of 8 000 gal.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the Journal.]

CONCRETE PILES.

By Charles R. Gow, Member of the Boston Society of Civil Engineers.

[Read before the Society, May 15, 1907.]

The speaker can hardly treat of this subject as a specialist, since concrete pile construction has constituted but a comparatively small portion of his work and has been adopted and applied as much from necessity as from choice. From time to time, in the course of our business, we have been requested to suggest ways and means for overcoming foundation difficulties and have found it convenient in many cases to recommend some type of concrete pile construction to meet the conditions.

I am convinced, in the light of our experience, that concrete piles have come to stay and must be accepted by the engineering fraternity as a permanent addition to the list of foundation expedients. Like all innovations, however, it is susceptible of being overdone through excessive enthusiasm and the usual desire to try something new. Already there is evidence of this in a few cases that have come under the speaker's observation, when the new type has been used at a sacrifice of economy without any compensating advantage. In other cases a misunderstanding of the possibilities of these piles, or a lack of knowledge of their dangers, has led to serious results in construction. It will be well, therefore, for engineers who contemplate using this construction, to thoroughly familiarize themselves with the entire subject and not take too much for granted.

Economic considerations usually demand that a concrete pile shall be capable of replacing at least three or four wooden piles. To do this it must carry safely a load of approximately thirty tons. It must be borne in mind that the ground under and around the pile must ultimately carry this load, and since there is a limit to the carrying capacity of any soil, there must also be a limit to the load we can concentrate on one pile of ordinary section. For the subsoil conditions in this locality, the above load of thirty tons is probably a maximum safe limit.

During the past few years a variety of methods have been devised for making and driving concrete piles. Each method

has introduced novel and ingenious ideas of considerable merit, but few, if any, have been free from objectionable features. It is a healthy sign that improvements are being continually made by the various inventors tending toward the elimination of these undesirable features. It is probably sufficient, for the present, to feel that even in the infancy of the subject we have our choice of several methods, any of which is capable of considerable possibilities if intelligently handled. I would especially emphasize this point, however: when the demands on a small concrete section are so severe, as in this case, a superior excellence of construction is absolutely essential. Other things being equal, therefore, the method which seems to guarantee this result with the minimum risk is the most desirable. Since none of the methods in present use entirely eliminates the element of risk, there is always a chance for intelligent study by the engineer before finally making his choice. For the reasons stated, our firm has made it a practice not to adhere to any one method but to recommend different methods for different conditions, as our judgment dictated.

In general, concrete pile construction may be divided into two classes, viz., piles built in place and those cast and driven. Both methods possess certain advantages as well as limitations. In the first class, the inaccessibility of the space where concrete is being placed, and the uncertainty as to what takes place during and after placing the concrete, is apt to leave some doubt as to its final sufficiency. In the second class, while the quality of construction is apparent with even superficial inspection, the possible danger during driving is extremely problematic.

As being of possible interest to the Society, I will enumerate some of the methods which have been used by us, together with the reasons for their adoption. Our first experience with concrete piles occurred about five years ago. An outbreak of quicksand had occurred in the basement of a mill building of rather heavy construction and in a few days had so damaged one corner of the building as to necessitate tearing it down. The remaining walls were threatened and indicated some settlement. Borings developed the fact that the building rested upon a thin stratum of hard pan overlying a bed of quicksand 25 ft. in depth. Below the quicksand was a stratum of very coarse gravel charged with water under a head, the elevation of which was 14 ft. above the basement floor. It was decided to drive piles to the gravel in two rows, one inside and one outside the line of the walls and to support the wall on needles capping the piles. Driving wooden

piles was out of the question, as the headroom required for the driving would necessitate removing the floors. Also the heavy jar produced by the driving would disturb the ground and tend to further settle the walls. At our suggestion the following method was adopted:

Eight-inch wrought-iron pipe in 5-ft. lengths was tapped down with a light hammer, the successive lengths being coupled together until the bottom section rested in the gravel. The pipe was then washed out with a water jet, thus removing all the quicksand. A 1-in. pipe perforated for 2 ft. on the lower end was then inserted and driven into the gravel for about 3 ft. Grout was forced into the 1-in. pipe, the intention being to form a ball of grouted gravel under the bottom of the 8-in. pipe and also to seal the bottom of the pipe against the inflow of water. After the grout had set, the 8-in. pipe was pumped out and filled with concrete. Two of these piles were subsequently used as a support from which to jack up some floors which had settled, and an estimated total pressure of 70 tons, or 35 tons on each pile, was applied without any measurable settlement of the piles. This method has since been used in a variety of cases, sometimes with slight modification. Its great disadvantage lies in the cost due to loss of pipe. On the other hand, it forms an exceedingly strong column, and, provided the foundation under it was sufficient, would carry tremendous loads. Such piles are commonly used in and around New York City in underpinning work, and the engineering press recently described their use in a new downtown building in that city, the pipes being 12 in. in diameter sunk 90 ft. to ledge and figured for as high as 116 tons each. In this case a reinforcement of round bars of large section was used, the steel being figured in compression.

A short time after this experience we were confronted with the following problem: A large brick building in the North End of this city had been originally constructed with the outer walls supported on piles and the inner partition walls resting on mud-sills. These interior walls settled until the floors were in an unsafe condition and repairs imperative. In this case the underlying soil was a 15-ft. layer of black mud and filling overlying blue clay. Old walls and timbers in the filling admitted tide water freely, so that an open excavation would require steam pumping, with the consequent danger of removing much of the mud, thus producing further settlements. The pipe method as used in the former occasion was inapplicable, since the clay bottom would take no grout and the piles would have a bearing

equal only to the area of the pipes. Figured on this basis, an excessive number of pipes would be required. This condition led to the invention of our chambering system, shown by Fig. 1. Eight-inch pipes are driven as before about 1 ft. into the clay and washed out. The washout drill is allowed to excavate for a further distance of 2.5 ft. below the bottom of the pipes and is then withdrawn. An expanding cutter of simple construction is lowered to the bottom of the pipe so as to rest in the clay below its bottom. By revolving the cutter, a circular chamber is formed 3 ft. in diameter on the base, and in shape approximately a frustum of a cone. The chamber and pipe are then filled with concrete. The result is a concrete shaft resting on an enlarged base. While we usually recommend leaving the pipe in, we have also on many occasions withdrawn the pipe as the concrete filling progressed. This system has been found particularly useful in inside work, although we have employed it in many cases in the open where it seemed to offer advantages.

Some time later the use of these chambered piles was suggested in the building underpinning operations connected with the construction of the Washington Street tunnel. It was our impression, however, that they were unsuited for this purpose since they would be subjected to lateral pressure during the period of adjacent excavation. As the practicability of the washout method is limited to pipe sizes up to about 14 in. in diameter, a very small section would be available to resist this lateral thrust. To meet this requirement, we abandoned the chambered pipe system in favor of the caisson method, similar to that in common use in Chicago during the past ten years, although at the time the idea was original as far as we were concerned.

By means of this method a pile of any diameter from 3 ft. upward may be constructed in the following manner: A circular excavation of the required diameter is started from the surface by means of pick and shovel. When the excavation has progressed a few feet in depth, a cylindrical steel lining in two halves is inserted and the halves are bolted together. This forms a lining which maintains the shape of the hole and protects the workman. As excavation proceeds, additional layers of steel lining are lowered to the workman, who inserts them under the first lengths and bolts them together. The sections of linings, being in two halves, are easily passed up and down through the shaft. When excavation reaches clay or other firm material, a chamber may be excavated to any reasonable diameter. The whole excavation may then be filled with concrete, the steel lining

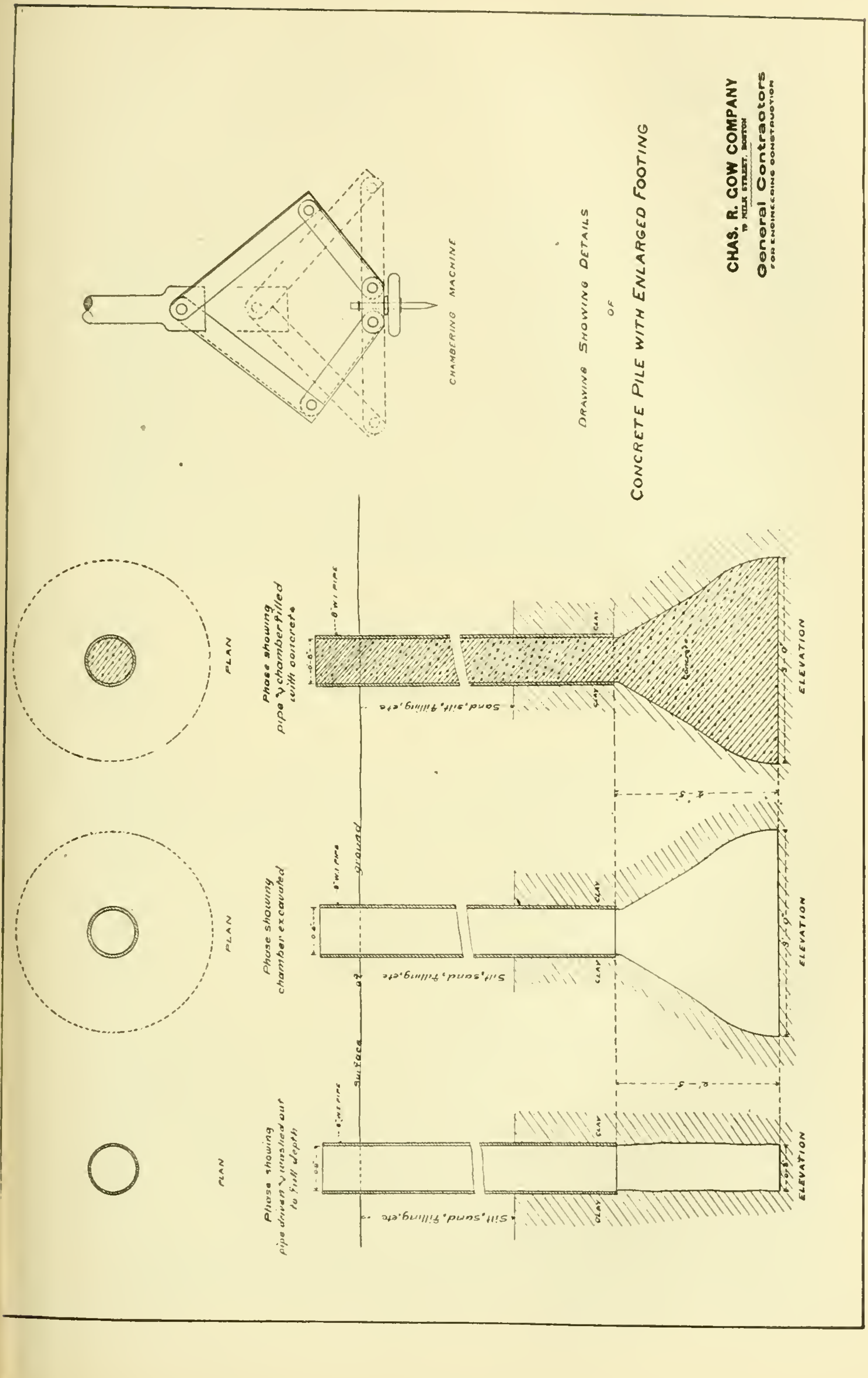

CHAS. R. COW COMPANY
General Contractors
Drawing Showing Details of Concrete Pile with Enlarged Footing
Chambering Machine
PLAN
PLAN
PLAN
Phase showing pipe driven & washed out to full depth
Phase showing chamber excavated
Phase showing pipe & chamber filled with concrete
surface
ground
Silt, sand, filling, etc.
Sand, silt, filling, etc.
CLAY
ELEVATION
ELEVATION
ELEVATION

FIG. 1.

being removed, section by section, as the concrete rises in the shaft. In sections where the ground penetrated is too unstable to stand at all, as in the case of running sand, the lining is made of a series of whole cylinders about 6 ft. long each, but of varying diameters to allow each successive length to telescope through the previous section and to penetrate 6 ft. in advance of it. This type of pile has proved remarkably economical and practical for heavy concentrated loads. We have on one occasion constructed a 15-ft. diameter chamber under a 3-ft. shaft excavation. The required diameter of the chamber, of course, depends upon the total load to be carried and the unit-bearing capacity of the soil. A caisson pile having a 3-ft. diameter shaft and a 9-ft. diameter chamber in good clay is safe for a load of 250 tons. The chief advantages are the minimum of excavation required, absence of concrete forms, and the consequent increase of progress.

By far the most interesting case of concrete pile work we have yet handled is that of the Milton car barn foundation for the Boston Elevated Railway, on which we are now working. The site of the work, covering a little less than an acre, is one of the most peculiar ground formations ever met with in our experience. Surrounded on all sides by ledge, the lot itself is a deep deposit of semi-fluid mud and quicksand extending to a maximum depth of 40 ft. The mud and sand are interspersed with what appear to be floating masses of hard pan, and at times beds of gravel overlying the quicksand are encountered. There seems to be no particular order or relation between the different classes of ground, and to further complicate matters the ledge bottom itself is so irregular that variations of 10 ft. in depth sometimes occur in a few feet distance. As the entire ground is thoroughly saturated with water, wooden piles would have been sufficient except for the possibility of future drainage if the ledge divide was ever penetrated. Concrete piles built in place were considered dangerous on account of the extreme depth and the unstable surrounding soil. The only alternative was the driving of cast piles, and this was the system finally adopted. Soundings were made at the location of each pile. A 0.5-in. gas pipe was coupled to a water hose fed by city pressure and jetted down to ledge. In this manner the exact depth from the surface of the ledge was determined for each location and a pile cast and numbered to correspond.

The proposed building covers an area of approximately 37 000 sq. ft.; 414 piles are required, ranging in length from 1.5 to 40 ft. All piles up to 6 ft. are built in place in a wooden

Fig. 2. Group of Cast Piles Ready to be Driven.

Fig. 3. Section of Finished Floor showing Concrete Pedestals over Piles.

form. A low wall of concrete capping the outside lines of piles supports the building walls, while interior loads are, for the most part, carried on columns resting on a single pile. Each interior pile is capped with a block of concrete 2 ft. square, in the top of which is set a dowel to take the wooden column. To prevent any lateral motion in the soft mud, the original plans contemplated the use of concrete tie beams in four directions. Owing to the difficulty of trenching for the beams in the semi-fluid mud, and the absence of any foundation on which to lay the concrete, this feature of the construction was changed at our request to the use of a 6-in. slab of concrete covering the entire lot and surrounding the pile heads. This slab rests upon a 6-in. bed of cinders overlying the mud. It is reinforced with poultry netting crossed in two directions. As the slab floats on the mud, precautions were taken to break its bond around the piles and against the walls by the insertion of tarred paper in order that it might settle evenly if at all.

The piles were cast with a square section 13 in. on a side, and since they were to act as bearing piles no taper was given them. The mixture was a 1 : 2.5 : 4 concrete. Clinton electrically welded wire cloth was adopted as a reinforcement, having 0.25 in. longitudinal wires 3 in. on centers. This reinforcement was bent to such shape as to make a continuous reinforcement 2 in. inside the face of the piles on all four sides. A line of tin speaking tube 1.5 in. in diameter was built in at the center of the pile to admit water for jetting purposes. This tube was stopped about 10 in. from the head of the pile and, by means of an elbow and threaded nipple, projected through the side of the pile to allow of attaching the pressure hose. The piles are handled with guyed derricks and inserted in a timber guiding frame containing a pair of driving gins. As soon as it is properly centered the jetting hose is attached to the nipple, and water, supplied by a steam pump at 100-lb. pressure, is forced through the interior tube and out of the bottom of the pile. It has sometimes been found expeditious to churn the pile up and down during sinking by means of the derrick. This action appears to thoroughly loosen the surrounding ground and allows a freer escape of the material below the pile.

As stated, at intervals all over the lot thin layers of hard pan are encountered, apparently floating in the mud and sand. It has been necessary to drive the pile through these masses when encountered. Much apprehension was felt as to the possible damage which might result from the driving of these piles. A

wooden follower has been used, resting on the pile head, and a 2 800-lb. hammer dropped from as high as 20 ft. has failed to produce any apparent injury. In the case of one pile the sounding pipe used in determining the necessary length of pile had penetrated a narrow crevice between two bowlders and the pile was cast to the length so found. Upon attempting to drive this pile, the space between the two bowlders proved to be too small to admit it. Not knowing what the obstruction was, the foreman attempted to drive through it. Three hundred blows of the 2 800-lb. hammer dropping 12 ft. were given without appreciable penetration, and rather than cut off and waste about 6 ft. of undriven pile, it was determined to pull the pile out and replace it with a shorter one. Upon withdrawing the pile, it was found to be perfectly sound and uninjured, except that the point had been slightly worn away on each side where it had rested against the two bowlders. Each pile is finally driven until it brings up firmly on the ledge.

The extreme length of many of the piles introduced the serious question of how best to handle them and avoid breakage. It was found that up to 30 ft. in length they could be picked up by the end without producing any undue strains, but when over 30 ft. they almost invariably cracked in the middle. To prevent this action, four angle irons were at first used strapped to the four corners of the pile by means of iron clamps. This method was effective, but the time required in placing and removing the irons rendered it impracticable. A simpler device was finally adopted which has allowed the handling of piles up to 40 ft. in length without damage. A long chain is used, one end being wrapped around the pile near the center, while the other end is similarly wrapped near the top end; the hook of the hoisting fall is hooked into the long loop of the chain, and as the pile is hoisted the hook slips along the chain toward the top as the pile is gradually upended. By this means, while the pile is in a horizontal position, the strain is applied almost equally at the two points of attachment and prevents undue stresses at the center of length. Once in an upright position, of course, no further precautions of this nature are necessary.

The time required in driving a pile depends entirely upon the nature of the ground penetrated. A 35-ft. pile has been put down in 9 minutes, while piles one half that length have sometimes required 3 hours.

In some cases difficulty was encountered in maintaining the pile in exact location, due to underground obstruction deflecting

Fig. 4. Cast Piles 36 Feet Long, being Handled by Derrick Preparatory to Driving.

its course. The maximum variation of this nature thus far noticed has been about 6 in., and fortunately has occurred under walls where the objection is slight as compared with its possible occurrence under columns, in which case a single pile supports the concentrated load.

This work was started late in November of last year. The early and severe freezing spells of that time caught us unprepared, with the result that about 75 piles were badly frozen. A thick covering of hay proved inefficient, as did also lines of steam pipes under the hay, spaced 10 ft. apart. Many of the piles were frozen before taking an initial set, and all of them before final set. Work on casting was then suspended until a shed could be constructed in which to cast the remainder. All attempts at protecting the frozen piles were abandoned and they were left to their fate, suffering alternate freezing and thawing throughout the winter. Late in January one of these piles was sent to the Watertown arsenal, thawed out, and immediately thereafter tested for crushing strength. It failed at 60 tons, or 710 lb. per sq. in. This test was deemed sufficient by the building department to warrant the condemning of the entire lot of frozen piles, but at our request a second sample was selected at random from the frozen lot and, accompanied by one of equal length taken from the lot cast under cover, was sent to the arsenal for a second test. This time the frozen pile was allowed to remain in a warm room after thawing for about 4 weeks before testing. It failed at 236 tons, or 2 800 lb. per square inch. The unfrozen sample failed at 241 tons, or 2 852 lb. per square inch. It would appear, therefore, that the frozen pile recovered practically all of its strength as soon as the freezing action was permanently removed. All of this lot of piles have since been driven. In a few cases the extreme ends of the frozen piles appeared to be slightly disintegrated. In such cases we cut off the ends exposing the reinforcement and recast them. Some of the piles thus repaired were driven within a week without injury to the new heads. In the case of one of these piles the head was shattered when the pile was within 3 ft. of grade. A new head was cast in place, the pile allowed to stand for a week, and it was then successfully driven to grade.

Some of the piles in this work have been successfully driven through material that the 0.5-in. sounding jet penetrated with the greatest difficulty, and if tapered they could probably be driven through any material that a wooden pile would penetrate.

As the work was suspended for the winter after casting the piles, no information was obtained as to how long after casting

the piles could be handled and driven. It is probable that if cast in warm weather they could be handled in two weeks without injury.

As this work was the first of its kind in this vicinity, there was no available previous experience to guide us. Consequently, as might have been expected, mistakes were made in many details.

With the idea of saving expense for forms, the ground was leveled off and covered with tarred paper on which was placed the side forms for each pile. The soil was so soft, however, that it settled under the load of the green concrete from one to three inches, resulting in a great waste of concrete and adding materially to the weight of pile to be handled.

These piles, if built as designed, weigh 175 lb. per linear foot, and the longest ones, therefore, weigh about 3.5 tons. It may be readily understood that the handling of such a heavy load requires extreme care at all stages of the work. Owing to the fact that our piles were cast in many instances at a considerable distance from the point where they were to be driven, much time was lost in moving them to the driver. Another time we should attempt to so lay out our work as to bring each pile within easy reach of the driving apparatus which was to drive it.

In the case of friction piles, some knowledge will be necessary as to the ability of concrete piles to penetrate different soils. Otherwise the lengths will be very indeterminate, and much waste of material and labor must result. For such piles a slight taper will probably assist the driving through firm material.

One important point to be considered in cases where the water jet method is contemplated is the displacement of soil which takes place owing to the jet action. This displacement in such soil as mud and fine sand appears to be something greater than the actual contents of the pile. This probably does not signify that voids have been left in the ground below, but rather that the disturbed soil has been altered in density, and a resulting shrinkage or subsidence may occur in the future as the material gradually returns to its original condition. An interesting feature of the Milton work in this connection has been the tendency many times for the water from the jet to reappear, not around the pile being driven, but in some cases around some other pile already driven, or perhaps through some old test pipe hole from fifty to one hundred feet away. Meanwhile the ground in the vicinity of driving has risen from one to one and one-half feet in elevation.

In conclusion I will say, it is my belief that cast concrete piles are a success in the same sense that all types of concrete piles are successful, and that they compare favorably in cost with those built in place. As before stated, I believe that neither type is universal in its application; that both have their limitations, and that there still remains a vast field for the continued use of wooden piles.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the JOURNAL.]

THE SIMPLEX SYSTEM OF CONCRETE PILING.

By Thos. MacKellar, Member of the Boston Society of Civil Engineers.

[Read before the Society, May 15, 1907.]

Among the various methods employed nowadays in the construction of foundations for buildings and structures of all kinds, concrete piles are beginning to play such a large and important part that they must be recognized as one of the standard methods of foundation construction. While it is known that so far back as the early lake dwellers of Europe wooden piles have been used for foundations or to keep foundations in place, it is not until comparatively recently that concrete piles have been used successfully. In the search for some material more lasting and durable than wood with which to build up a pile, engineers in France first conceived the idea of driving down a form of wood or some other material, withdrawing it and filling the resulting hole with wet sand thoroughly rammed into place, thereby causing the whole ground to be highly compressed and capable of sustaining large loads, forming a foundation of what is known as sand piles. This might be considered as the first intermediate step between wooden piles and concrete piles.

The continued and increasing demand for some permanent form of pile that would resist the destructive action of air and water, as well as other enemies, brought many minds to bear on the subject. About thirty years ago a patent was taken out in this country for producing concrete piles by driving down a solid steel tapered form, withdrawing it, and filling the resulting hole with concrete.

This was not a commercial success, however, as in most cases the ground tended to collapse upon withdrawing the form, making it impossible to properly fill the hole with concrete. At the Paris Exposition concrete piles 36 in. in diameter were formed by dropping a heavy conical plumb-bob weighing 10 000 lb. from a height of 30 ft. This process was repeated until a hole about 30 ft. deep had been formed, which was then filled with concrete. This was a slow and expensive process and worked successfully only in ground that was moderately hard. Little further was heard of it.

It remained for the French engineer, Hennebique, to produce the first concrete pile that was put into actual use and that proved to possess commercial value. His method was to cast a strongly reinforced concrete pile in a mold, allowing it to set hard, and then driving it in the same manner as a wooden pile. This was a great improvement over anything that had yet been brought out, but still possessed certain disadvantages. To avoid the shattering effect on the concrete of direct impact it was necessary to use a special drivehead, the interior of which was filled with sawdust to soften the force of the blows. It was necessary to cast a large number of these piles beforehand, as it would be scarcely safe to handle them under less than thirty days set, and a large space was necessary for their proper handling and shipping. Besides Hennebique's pile, there are a number of others which are molded, allowed to set, and then driven or jetted down.

The next type of concrete pile was produced by Raymond, who used a collapsible tapered steel driving form, around which was tightly fitted a thin sheet-iron shell of about No. 20 gage. The combined form and shell were driven to the required depth, the form was collapsed and withdrawn, leaving the shell in place in the hole, which was then filled with concrete. The resulting pile consisted of a concrete core surrounded by an iron shell, which in time rusted away.

The Simplex concrete pile was the next to enter the field, and will form the subject matter of this paper. First adopted by Capt. J. S. Sewell, Corps of Engineers, U. S. A., for the foundations of several buildings at the Washington barracks four years ago, its use has since become so widespread and successful that at present it is being specified by several of the largest railroads and numerous architects and engineers throughout the country. The first idea brought forth was to drive a wooden form to the required depth, withdraw it, and fill the hole with concrete. This method was found to be unsatisfactory, due to the tendency of the sides of the hole to collapse upon withdrawing the form, and was soon discarded. A hollow steel form was then tried, on the bottom of which was placed a molded concrete point. This form, resting on a shoulder molded around the top of the point, was driven down to the required depth, and then withdrawn, the point remaining at the bottom of the hole, and the necessary amount of plastic concrete was filled into the hole simultaneously with the withdrawal of the form.

This method was found to work in a perfectly satisfactory

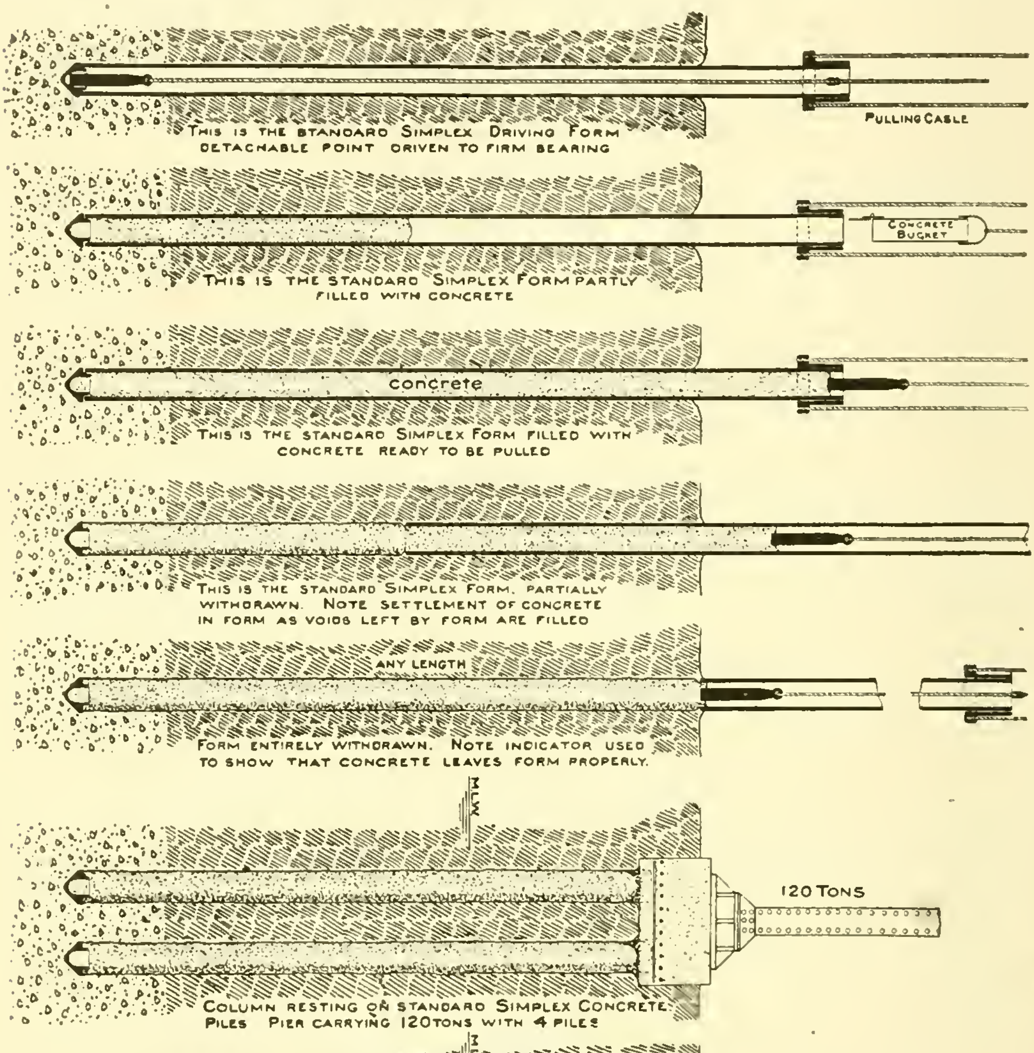
manner and to give good results, but still showed that there was room for improvement. It was necessary to cast a large number of the concrete points in advance in order to allow them to attain a hard set before driving on them, and this necessitated a large storage place, with capacities for handling and shipping the points. Also there was the liability of the concrete's shattering under the repeated heavy blows of the hammer, thereby producing an imperfect pile. Finally it was decided to use cast-iron shell points, for the reasons that they were less expensive, easier to handle, required less storage space; in fact, being shipped direct from the foundry to the work, would stand a great deal more battering than concrete, and, being very blunt, would furnish an excellent end-bearing. Although this loose point method of driving the piles was the most successful that had yet been tried, it did not seem right to have to leave a cast-iron point at the bottom of each pile, practically amounting to throwing away so much money every time a point was used, and increasing the cost of the finished pile. Finally Mr. Constantine Shuman, chief engineer of the Simplex Concrete Piling Company, conceived of the idea of attaching, by means of a cast-steel sleeve, to the lower end of the driving form, two cast-steel jaws in such a manner as to allow them to swing freely.

These jaws are segments of a true cylinder the same size as the sleeve, formed by two planes, one cutting in at approximately 30 degrees to the axis and the other at right angles to the first and intersecting a little short of the axis. When brought together they form a sort of a clam-shell point, perfectly tight and well adapted for penetrating the ground. When hanging open, they form a true cylinder of the full size of the pipe above and give a straight and unobstructed chute for the passage of the concrete. In practice the jaws are closed and kept that way by the pressure of the earth against them in driving, and the form is driven down to the required depth. Upon withdrawing the form the jaws open of their own weight and permit the passage of the concrete past them. To obtain perfectly satisfactory results by this method, the ground must be firm and compact, as any back pressure in the ground tends to partly close the jaws, thereby reducing the diameter of the pile and rendering it imperfect. Owing to this the use of the " alligator point form," as it is called because of its resemblance to a giant saurian, has never become general but is used only in a few localities where ground conditions favor it. This meant a return to the loose points, which is the method in general use to-day by all the companies operating under the Simplex patents.

The apparatus employed in driving Simplex piles is built along the same lines as the ordinary wooden pile driver. Owing to the nature of the work it is called upon to perform, however, it is much heavier and more complicated, inasmuch as it has to withdraw the form after it has been driven into the ground the necessary distance, something which the wooden pile driver does not have to do. Everything about the whole apparatus is made of as rugged and simple a nature as economy in cost and handling will permit. The 3 300-lb. hammer strikes on a hickory block set in a steel drivehead which rests on top of the driving form. The wooden block is found necessary to lessen the upsetting action of the powerful blows of the hammer on the top of the form. The driving form is made up of a single 40-ft. length of 16-in. diameter steel pipe, 0.75-in. metal, at the top of which is fastened, by means of twenty-four 1-in. csk. rivets, a boiler steel band 0.5 in. thick and 18 in. deep. This band serves the double purpose of reducing the upsetting action on the form due to the hammer, and for use in pulling the form. The form rests on a shoulder at the top of the point and is kept centered by means of a tenon on the point which engages with the inside of the form. The point itself is hollow, 10 in. deep, 16.5 in. in diameter, and has a projected sectional area of 1.4 sq. ft. The form is withdrawn from the ground by means of two 1-in. steel cables fastened to a steel collar, which engages under the reinforcing band at the top of the form. The cables pass in the channel leads on each side, over the head of the driver and down in back to a pair of fivefold steel blocks, the lead-line from which passes to one of the drums on the engine.

In this manner the power of the drum is increased ten times, and it is no uncommon thing to break the pulling cables when the form is in hard ground. To illustrate the force necessary at times to withdraw the form, while on some work in South Boston last fall for the New York, New Haven & Hartford Railroad, on one pile our form struck a heavy timber about 25 ft. below the surface and on being driven through it became wedged in it tightly. Before it was withdrawn, besides our regular pulling rig, we were using a fall of double hemp blocks and two 30-ton jacks. Upon redriving the form it became wedged again, and in spite of the fact that we this time put the two jacks at the end of a lever, which doubled their capacity, and used an extra set of fivefold blocks, the form had finally to be abandoned and left there to take the place of the ordinary pile. Fortunately this is a very rare occurrence.

The general method used at present in driving the Simplex pile is about as follows, being changed slightly to meet varying conditions: The form, resting on a cast-iron point, is driven to hard pan or whatever bearing and penetration are obtainable and



necessary to carry the required load. A heavy weight is then lowered into the form to make sure the point is loose. While the weight is at the bottom of the form a target is placed on its line at the top of the form, the purpose of which will be apparent later. The weight is then withdrawn. Given the length of the pile and

sectional area, it is an easy matter to determine the volume of concrete necessary to fill the hole.

This amount is put into the form by means of a specially-designed bottom dump bucket, which permits the concrete to leave it in one mass, reaching its destination with practically no disintegration. It will be noticed that when the full amount of concrete is in the form its surface is considerably above the surface of the ground. This is due to the fact that the thickness of the form occupies considerable space that is to be occupied by the concrete. The weight is now placed on top of the concrete and the form is pulled. The target previously mentioned now becomes useful. As the form is withdrawn the concrete settles down to occupy the space left by the walls of the form. Obviously this settlement should proceed at a uniform rate, and as it is difficult to watch the weight, the target on its line further up is of considerable help. By watching this target in connection with a scale on the leads of the driver, it can be readily told how the concrete in the form is acting. As another check, the target, just as the bottom of the form is leaving the ground, should be level with the top of the form. This would indicate that the necessary amount of concrete has gone into the ground and that, other conditions being all right, the pile is a good one. In some grounds where the head of concrete in the form exerts a greater pressure than the back pressure or resistance of the earth, the concrete will be forced out into the sides of the hole, making the pile of increased diameter at that point and necessitating the use of more concrete to bring the pile up to the required level.

This, of course, is no objection. One great advantage of the loose point method is that in withdrawing the form and placing the concrete the end bearing is in no wise disturbed and you know that you are getting the full advantage of the hard driving and small final penetrations. The presence of water in the soil causes no trouble, as the form is practically watertight under ordinary conditions, and can be made absolutely so if necessary.

Thus driven, the Simplex concrete pile is a rugged, monolithic column, 16 in. in diameter from top to bottom. The concrete, leaving the form, forces itself into intimate contact with the surrounding earth, cementing itself to any rocks, brickbats, or bowlders it may have encountered, and presenting an extremely rough frictional surface to the ground around it. This question of side friction is interesting and is worth considering for a few moments. It is on this side friction that piles depend to carry the greater part of their load, and the value of this friction depends

on the character of the ground. In most instances where piles are necessary the frictional value increases with the depth, so that the ideal pile would be the one which took the best advantage of this and placed small reliance on the upper poor ground. A comparison of the various piles in this respect is interesting and shows clearly how the loads are transmitted to the surrounding ground.

There are on the market at present practically only three styles of piles, — the ordinary wooden piles, the tapered concrete pile, either molded before driving or made in place, and the cylindrical concrete pile.

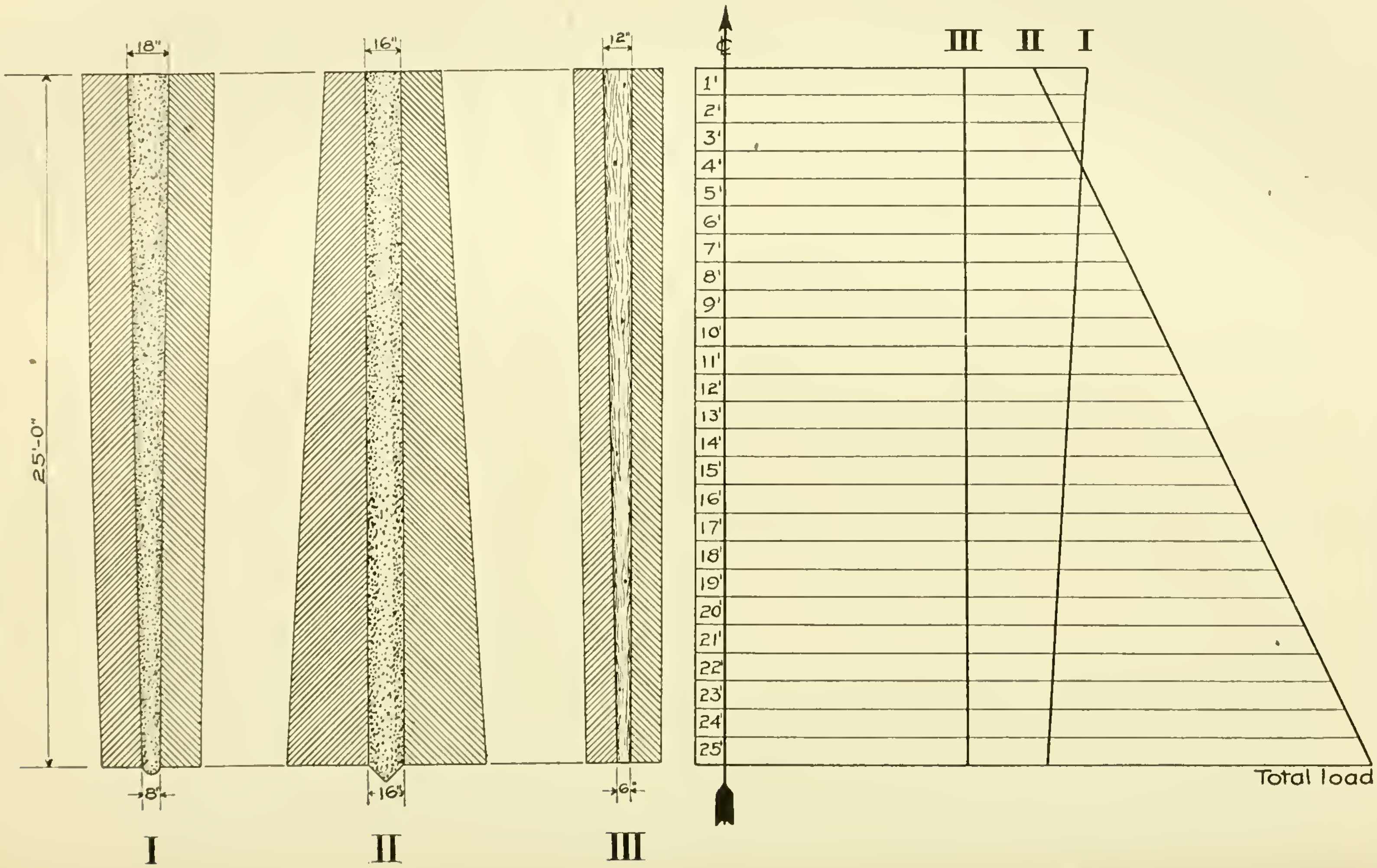
For the purpose of comparing these piles let us assume ground conditions which will bring out the most good points of each system, making the comparison as fair as possible to all concerned. Assume that the ground is of such a firm and compact nature that one square foot of pile surface at the butt of the pile will develop a carrying capacity of 0.35 ton, increasing uniformly to 0.7 ton per square foot of pile surface at the point of the pile. Assume each pile to have been driven 25 ft. into this ground. Also assume the ultimate friction of the concrete and wood against earth to be the same, and neglect the end bearing values of the piles. Then we have the superficial area for one linear foot of pile at the butt and at the point for each pile to be as follows:

Pile.	I.	II.	III.
Butt	4.71	4.2	3.14
Point	2.1	4.2	1.57

Multiplying these areas by the unit loads for the butts and points of the piles and scaling them off as shown on the plate, and connecting the upper points with the lower points, diagrams are obtained which show, not only the total loads carried due to superficial friction by the piles, but also show how the loads are transmitted to the surrounding earth. The diagram shows this more in detail and also shows a table giving the loads carried by each linear foot of pile as scaled from the diagram. The diagram of pile I shows that a slightly greater load is transmitted to the surrounding ground at the butt of the pile than at the point.

In other words, the very reason for the use of piles is defeated by placing over half the load on the poor upper earth. The diagram for pile III shows that the loads are very uniformly distributed to the surrounding ground for the whole length of the

HALF OF DIAGRAM SHOWING CAPACITY OF PILES PER LINEAL FOOT.



Load per lineal foot.			
Foot	I Tons	II Tons	III Tons
1	1.652	1.470	1.100
2	1.640	1.530	1.100
3	1.634	1.590	1.100
4	1.628	1.650	1.100
5	1.620	1.710	1.100
6	1.608	1.770	1.100
7	1.602	1.830	1.100
8	1.594	1.890	1.100
9	1.588	1.954	1.102
10	1.578	2.014	1.102
11	1.572	2.080	1.102
12	1.566	2.140	1.102
13	1.558	2.200	1.102
14	1.552	2.260	1.102
15	1.544	2.320	1.102
16	1.536	2.386	1.102
17	1.530	2.446	1.102
18	1.522	2.508	1.104
19	1.514	2.570	1.104
20	1.506	2.630	1.104
21	1.500	2.690	1.104
22	1.492	2.750	1.104
23	1.486	2.814	1.106
24	1.478	2.876	1.106
25	1.470	2.940	1.106
	38.97	55.018	27.56

pile, which is little better than pile I. The diagram for pile II, however, shows that small reliance has been placed on the carrying capacity of the upper earth, and that by far the greater part of the load is transmitted to the ground around the bottom of the pile. In other words, it shows that as the carrying capacity of the earth increased, the pile placed a greater load on it, thereby developing the power of the ground in a rational and logical manner. Piles I and II place the *greatest load where the earth is weakest, and reduce the load as the soil becomes stronger.* Aside from this it will be noticed, in summing up the loads carried by the various piles per linear foot, that pile III carries the smallest load, pile I next, and that pile II will carry more than twice the load of pile III, and over half again as much as pile I. In all this discussion the end bearing of the piles has been neglected. To look at this point for a moment, it will be noticed that pile I has an end bearing of 0.34 sq. ft., pile II an end bearing of 1.4 sq. ft., and pile III has an end bearing of 0.2 sq. ft., or, in other words, pile II has an end bearing equal to four times that of pile I and seven times that of pile III. Assuming in the soil discussed above that the end bearing will develop 5 tons per square foot, then pile I will develop 1.75 tons, pile II, 7.0 tons, and pile III, 1.0 ton.

The advantages of Simplex concrete piles over wooden piles and other forms of foundation construction under certain conditions are so obvious as to hardly need recounting, but it can do no harm to recall a few of them. Compared with wooden piles, concrete piles possess great durability and are not subject to destruction by rot or the attacks of insects which are so destructive to wood. They can be used in any place where wooden piles can be driven and in a great many places where they cannot. An important point to be noticed is that concrete piles save from 20 per cent. to 80 per cent. of the concrete in the footings, with the attendant necessary excavation, pumping, sheet piling, and so on, because no attention is paid to the water line. In comparison with deep footings or piers, a great saving is made not only in the concrete and excavation, but in many instances considerable time is saved. For instance, a column carrying 120 tons has to be supported and hard pan is 20 ft. below the surface. If the hard pan is good for 5 tons per square foot, then the pier would have to have 25 sq. ft. of area at its base. This would mean the excavation of a hole at least 7 ft. square from top to bottom, with the necessary sheet piling, shoring, and perhaps pumping, and would take a week or ten days to finish. Four Simplex piles would carry the required load, and could be driven in a morning,

Five 16-inch Simplex Concrete Piles. Crane Foundations for the Westinghouse Machine Co., Pittsburg, Pa., U. S. A.

Exposed, ready for putting on concrete cap. Note roughness of surface and cementation to the earth. These five piles were afterward tested with a load of 300 tons for ten days, under which there was no settle

after which all that would be necessary would be a capping about 2 ft. deep by about 5 ft. square, the whole operation consuming not more than two days' time.

A unique field for concrete piles is in the foundations of large stacks or water towers. Here they resist the overturning action, not by dead weight, but like the roots of a large tree, gripping the surrounding earth very strongly on account of their extremely rough surface. In France, recently, a reinforced concrete wharf was built, using Simplex concrete piles, heavily reinforced, for the foundations.

Simplex concrete piles were first used in the foundations of a number of buildings at the Washington barracks. As these buildings were rather light it was intended at first to extend the foundations just below the frost line, but the ground being regarded with suspicion, several tests were made, from which it was discovered that the earth was totally incapable of sustaining the required loads. Figures were gotten for installing the foundations by sinking caissons, using heavy concrete piers, wooden piles cut off below low water and by spread footings. These methods were all found to be too expensive, however, and the Simplex system was finally adopted as being the most economical. Some 6 000 piles were driven on this work, and the final results showed a saving of 10 per cent.

The great success of the Simplex piles at the barracks attracted a great deal of attention throughout the East, and in a short time they were adopted for the foundations of a post-office at Lawrence, Mass.; a train shed at Chester, Pa.; and for the Produce Bank Exchange Building in New York City.

Then, after a competitive test, it was adopted in the foundations of the Pittsburg Terminal and Warehouse Company's warehouse in Pittsburg, Pa. This was one of the largest pieces of foundation work ever constructed in this country. Piles to the number of 4 800 were driven on this work — a total of 162 000 linear ft., or 31 miles, all of which were driven in three months' time. The lowest time bid received for heavy concrete footings was eighteen months. The rental saved by using the Simplex system was almost enough to pay the entire cost of the foundations.

From this time on the Simplex system was rapidly adopted in foundation work throughout the country. It has been used for the foundations of sheds, stacks, bridge piers, retaining walls warehouses, foundries, traveling cranes, tall office buildings, residences, small office buildings, and, probably a unique field

for piles, under reservoirs. Here the piles are driven about 5-ft. centers under the floor of the reservoir and transmit the load of the water down to some firmer stratum of ground. In this manner the liability of the floor of the reservoir settling and cracking, with consequent leakage, is avoided and the piles are well worth the extra cost on this account.

Simplex piles, in nearly all kinds of ground, are driven to carry a load of 30 tons. To make sure of their ability to do this safely, many tests have been made on different work, some of them being of sufficient interest to mention here.

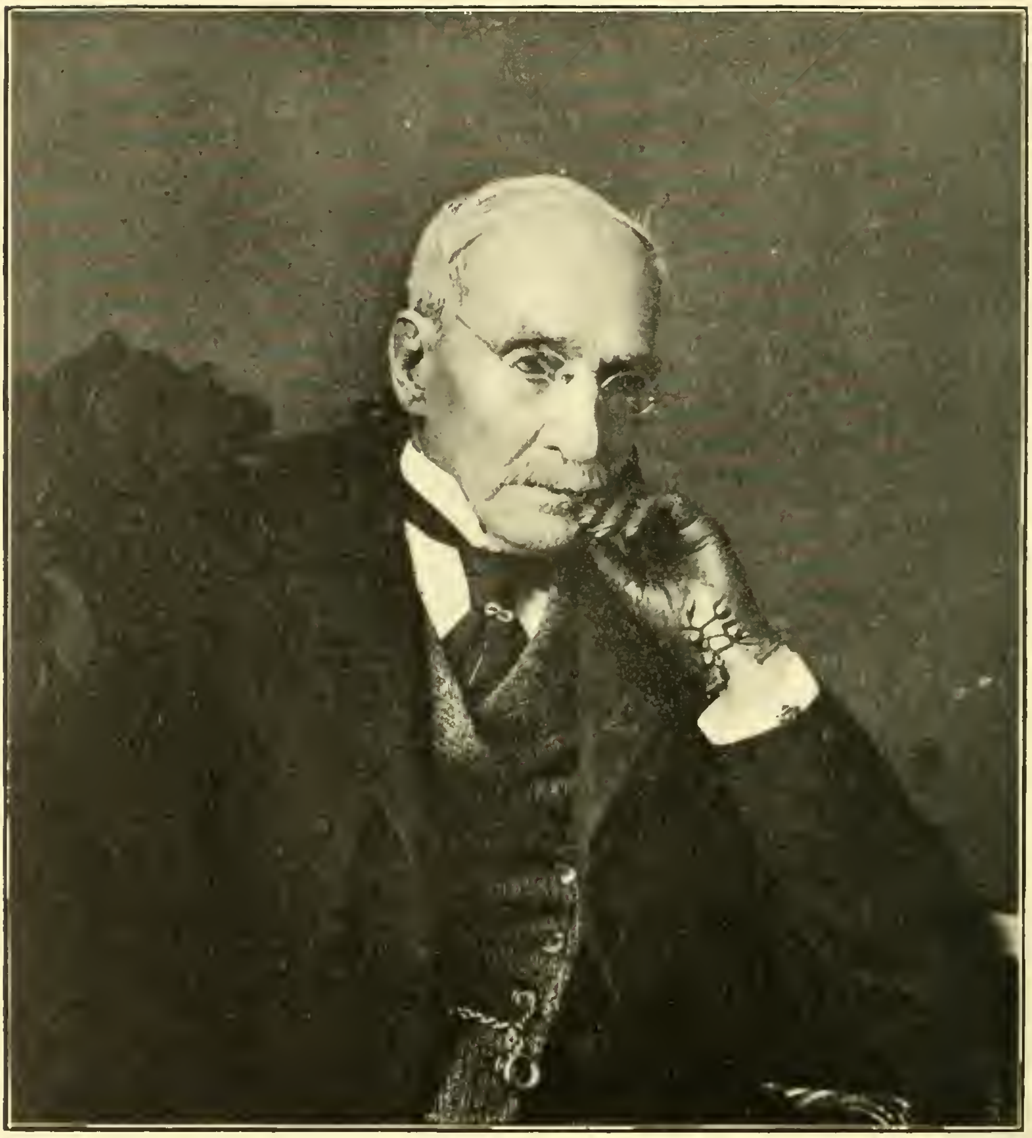
On the Pittsburg Terminal and Warehouse Company's work a cluster of four piles was selected at random and tested to 175 tons, showing no appreciable settlement, although the load remained on for a month and was close to the tracks of the Pittsburg and Lake Erie Railroad, being subjected to considerable vibration by the passing of heavy trains. On some work for the Westinghouse Machine Company, at Pittsburg, a cluster of five piles was tested to 300 tons, showing no settlement. In New York several piles were tested to over 45 tons with no settlement. In France recently a cluster of four piles was tested to a load of 245 tons without settlement. Throughout all these tests, and many more, the Simplex concrete pile has proved its ability to safely carry the loads designed for it, and we have yet to hear of the failure of any structure due to Simplex piles.

The question of the proper loading of Simplex piles is a matter of judgment and experience, depending largely on the character of the ground through which they are to be driven. In some cases they are carrying safely a load of 45 tons, and in others they are carrying as low as 15 tons. In all cases, however, it is safe to say they will carry a greater load, under the same conditions, than wooden piles.

There are at present nine companies in this country, one in Mexico, and five in England and Europe operating under the Simplex patents.

The system is controlled by the Simplex Concrete Piling Company, Philadelphia, Pa., who have developed the system from its early days, and who have designed all the apparatus used in its work.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the JOURNAL.]



Charles Haynes Haswell.

OBITUARY.

Charles Haynes Haswell.

HONORARY MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

IN the recent death of Mr. Haswell this Society has lost one of its Honorary Members and the profession has lost its dean.

Few deans have been distinguished by so long a life of activity and usefulness. Many have lived to be nearly ninety-eight years of age, but few have retained to the end both power of application and desire for work.

Charles Haynes Haswell was born in the city of New York on May 22, 1809. He died at his home, 324 West Seventy-Eighth Street in the same city, on May 12, 1907, from the effects of a fall in his dining-room which dislocated his shoulder.

The pain and shock proved too severe a strain for his great age, and the indomitable will and courageous spirit which had so often faced the dangers of life passed into the great unknown. Had Mr. Haswell been spared ten days more, he would have arrived at his ninety-eighth birthday. Two years more and he would have seen the full century mark on the journey; few can doubt, after considering his active physical and mental powers, that had his life been continued to this stage, the one hundred years would still have found him engaged in professional work. There was at the time of his death no more interesting figure in the whole realm of Engineering.

Mr. Haswell's death is a particularly significant event for this Society. He became a member on June 3, 1850, soon after the formation of the Society and before the organization of the American Society of Civil Engineers. He was therefore a member for more than fifty-seven years, and formed the link which connected the Society of to-day with that of 1848.

Let us now follow briefly the details of his active career.

Mr. Haswell's parents were of English origin, descendants from stanch Royalists, who, after the defeat of Charles II at Worcester, migrated to Barbados in the West Indies.

After an excellent education, of a somewhat classical flavor, young Haswell at the age of nineteen began his professional life by entering the well-known engine works of James P. Allaire;

here the rudiments of mechanics were soon mastered, and the alert mind of the apprentice turned to the more important work of design.

In 1829 Mr. Haswell married Miss Ann Elizabeth Bourne, of New York City, by whom he had three sons and three daughters.

In 1836 Haswell's attainments had become so conspicuous that the government invited him to enter its employ in connection with the enlargement of the navy, and for several succeeding years his energies were directed to the equipment of some of the most important vessels of war.

"Prior to 1839 the construction of all steam boilers was restricted to the ordinary merchantable plates of metal of uniform dimensions, but when the boilers of the United States frigates *Missouri* and *Mississippi* were designed, Mr. Haswell laid them down full size on the mold loft floor of the Navy Yard at Brooklyn, and defined the dimensions of each of the required plates to suit their location in the boilers, and in accordance with these dimensions they were rolled and trimmed. This was the first trial of such a proceeding and one that is now of universal practice." *

In 1850 Mr. Haswell's health became impaired. A board of surgeons declared him unfit for duty, but notwithstanding this fact he was ordered on service to the Mediterranean. It was found that the animosity of a clerk had prevented the finding of the board of surgeons from becoming public. Shortly after arriving in the East, it was plain that he was in no condition for work and he was returned home as "unfit for duty."

At other times, however, several voyages were made as chief engineer in charge of operation and maintenance of machinery of his own design. How much deeper and wider must have been the experiences of a mechanical engineer in those days, with the opportunity to witness at first hand the behavior, under actual trial, of machinery designed by himself.

An anecdote is related of young Haswell in connection with this period of his life which gives some idea of the strength and independence of his character. In fitting up the *Missouri* it was proposed to furnish her with horizontal smokestacks. Against this plan Mr. Haswell protested with so much zeal that he was suspended from duty for insubordination. It was afterwards shown by actual experience that the young engineer was correct and he was promised reinstatement if he would apologize to his superior officer, but this he refused to do, saying that he

* *Cassiers Magazine*, p. 440, 1900.

might be obliged to submit to injustice from others, but he declined to be unjust to himself. His career in the navy, however, was not destined to end with this incident for we find him soon again under pay of the Navy Department, and superintending the construction of machinery for four revenue cutters.

In 1843 Mr. Haswell assumed the duties connected with the office of engineer-in-chief of the navy, and in 1845 received formal appointment to that position which he filled until 1851. In 1848 he was a member of a board appointed to design four steam frigates; among them was the *Powhatan* which afterwards formed a part of the fleet under Perry at the opening of the Japanese ports. In the design of this frigate Mr. Haswell was obliged to make all of the working drawings, owing to a scarcity of men sufficiently skilled to be of material aid as assistants. The machinery for the *Powhatan* included some novel ideas, such as the setting of the engines in massive wrought iron frames. This frigate was retired from commission in 1886, at which time she still retained many of the original features of the design of 1848.

The task of planning so much machinery, together with other responsibilities, was enough to tax the energies of the strongest constitution, but when to this were added petty annoyances, jealousies and criticisms from those who really should have been his supporters, Mr. Haswell found that the office of chief engineer of the navy was no longer attractive, and in 1851 he tendered his resignation and entered upon the private practice of his profession in New York. He was in the prime of life and soon had ample opportunity to show to the world the high standard of his physical and moral endowments. Several merchant steamers were built under his direction, and he was frequently called upon in various directions to fill important positions. For a period of forty-two years, 1851–1893, he was surveyor of steamships for the marine underwriters of New York, Boston and Philadelphia. In 1858 he was elected president of the board of councilmen of the city of New York; later he became consulting engineer for the board of improvements, and on several occasions he acted as engineer for the board of health.

In 1862–63 Mr. Haswell was marine engineer of the Burnside Expedition and commanded a small steamer. At the bombardment of Fort Barton on Roanoke Island he ran her under fire to the assistance of the gunboat *Ranger* which had stranded on a shoal.

Many years after these events Mr. Haswell directed the

extensive improvements on Ricker's Island, and as late as the winter of 1905–6, during bitterly cold weather, he visited the work to see that it was properly executed. At the time of his death he was consulting engineer to the Board of Apportionment of New York City, and went three times a week to his office to perform the duties.

While Mr. Haswell's title to fame is founded primarily upon his design of the first steam yacht, the *Sweetheart*, which he launched in the East River in 1837, sometimes referred to as the Eve of vessels of her class, it is to his " Engineer's and Mechanic's Pocket Book " that he owes that wide familiarity with his name which exists in the profession. For more than half a century nearly every engineering office has contained a copy of this familiar book. It was first published in 1843, and since that time it has passed through seventy-two editions and has in the meantime grown from 284 to 1 051 pages.

In addition to the Pocket Book, Mr. Haswell contributed liberally to the literature of the societies with which he was connected. His " Reminiscences of an Octogenarian of New York City " covers the period 1816–60, and was published in 1897.

The social side of Mr. Haswell's nature was well developed and led him to form a wide circle of acquaintances. He was a member of the American Society of Civil Engineers, the Engineers' Club of Philadelphia, the Institution of Civil Engineers of London, and of naval societies in Great Britain and the United States. While at a convention of the Institution of Naval Architects of Great Britain in 1897, he was declared to be the oldest practicing engineer in the world.

He was dean of the Union Club in New York and was also associated with many other clubs. He was a constant visitor at the Engineers' Club of New York to the very last, and on the occasion of his ninety-fifth birthday a notable dinner was given him by this club; sixty-five covers were laid in honor of the veteran and a massive loving cup was presented to him. In replying to a toast Mr. Haswell gave reminiscences of his long life, and among other stories told he said that during his early career in 1837 he had occasion to recommend the construction of a towboat, but this was turned down by his superior officer who gave as his reason that there were already two towboats in American waters and there was no room for a third.

The long and picturesque life we have thus scanned as in a kaleidoscope has in turn gone to its long rest with the " great majority." Many a sun may rise and set before the engineering

profession is blessed with another member whose life and activities will be spared to as great a span. At the time of his birth, James Madison, the fourth President of the United States, was in office. There have been twenty-one Presidents since, so that Mr. Haswell might have seen twenty-two out of the twenty-five Presidents. When his eyes first saw the light there were but seventeen stars upon the flag, — Louisiana had not been admitted to the Union, neither had Maine; to-day the constellation numbers forty-five. Mr. Haswell was two years of age when the first steam printing press was invented; he was three when the intrepid Hull with the old frigate *Constitution* captured the *Guerrière*. He was five when the first vessel of war propelled by steam was launched at New York, and in that year Stephenson was already struggling to perfect the first locomotive. He had just passed his sixth birthday when Napoleon's long line of victories was broken at the battle of Waterloo and other military heroes blazed upon the horizon. Young Haswell was sixteen years of age when the Erie Canal was opened; he was twenty-eight when Victoria ascended the throne and eighty-eight when her diamond jubilee was celebrated, and at the advanced age of ninety-seven was still taking a deep interest in the procession of events precipitated by the active work of the different nations of the earth. A vast array of distinguished lives in all branches of human effort passed across the long perspective of his vision.

May the gallant struggle of Charles Haynes Haswell for the advance of the race, his long and well-tried faith in the achievements of man, and his undying loyalty to the best traditions of his profession prove an inspiration to guide our own lives toward the final goal.

Signed, Desmond FitzGerald.
Clemens Herschel.
Ira N. Hollis.

Frank Walton Upham.

Member of the Boston Society of Civil Engineers.

Frank W. Upham was born in Wayland, Mass., November 4, 1870, becoming a member of this Society April 17, 1901. Both of his parents were of old New England stock, prominent among his mother's ancestors being Samuel Whittemore, who lived in what is now Arlington, and who on the day of the battle of Lex-

ington, regardless of his eighty years, killed three British soldiers, was himself badly wounded but recovered to live until ninety-six years of age.

Mr. Upham received a high-school training in the town of Weston and immediately after graduating went to work for the late Mr. Frank P. Johnson, who at that time conducted a private engineering business in Waltham. After a two years' apprenticeship with Mr. Johnson, from whom he received most excellent recommendations, he entered the city engineer's office of Newton under Mr. Albert F. Noyes, and with the exception of a year spent with the Massachusetts Highway Commission, he remained there until it became necessary for him to seek a milder climate for his health. As an engineer, he was studious and painstaking. His notes and records remain a model of neatness and clearness. His kindly disposition won him many friends among his associates, with whom his memory will long linger.

In August, 1906, he married Miss Elizabeth F. Paddock, principal of the Franklin School in Newton. His home life was a very happy one and he became very much interested in church work, joining the Episcopal Church, of Auburndale, where he took an active part.

In his failing health very few, if any, of his friends realized his condition. With courage and cheerfulness he made his last fight, and it was with surprise and great regret that his friends learned of its being necessary for him to go to California to regain, if possible, his health.

After a stay of nearly a year in California, realizing he had not long to live, he greatly desired to see his home once more, so returned to Holliston, Mass., the present home of his parents, where after three weeks he passed away on the 3d of May, 1907.

While Mr. Upham's life, like that of many an engineer, was a quiet one, not distinguished by deeds proclaimed, yet to those who knew him intimately he stood out from among us by his quiet, genial manner and keen sense of humor, and he was one with whom it was always a pleasure to associate.

Irving T. Farnham,
Rowland H. Barnes,
Committee.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIX. NOVEMBER, 1907. No. 5.

THE CAUSE, TREATMENT AND PREVENTION OF THE "BENDS" AS OBSERVED IN CAISSON DISEASE.

BY PROF. J. J. R. MACLEOD, WESTERN RESERVE MEDICAL COLLEGE.

[Read before the Civil Engineers' Club of Cleveland, May 14, 1907.]

IN the employment of caissons in tunneling under rivers, and in the use of the diving suit in submarine engineering, it is well known, both to physicians and engineers, that certain peculiar symptoms are apt to attack the worker. The symptoms, popularly known as "caisson disease," or the "bends," or "the pressure," or "diver's palsy" may be of a very mild and transient character, or they may be of sudden onset and great severity, either leading within a short time to death or persisting with varying intensity until ultimately they leave the patient in a crippled condition.

Until comparatively recently there has been no systematic and competent investigation attempted of the cause of the disease. Affecting, as it does, only workers in compressed air, and not being, therefore, observed frequently by medical men, it received little attention until the year 1854, when Pol and Watelle,* two French physicians in charge of 64 men employed in a caisson on the banks of the Loire, published an account of the symptoms.

It would, of course, be out of place for me to give any detailed account of the symptoms here. Indeed, to do so would not only exhaust all your patience, but would occupy all my time, for the symptoms are of a very protean type; they may

* *Cit.* after Paul Bert, "La Pression Barométrique," p. 380.

be practically anything.* Perhaps, however, it may be well to briefly point out the main symptoms in a typically mild and in a typically severe case. And first of all let me point out that the symptoms never appear when the workman is in the compressed air; it is only after he has been decompressed that anything unusual is noticed. It is true that when he enters the compressed air he may feel somewhat uncomfortable; he may feel a stuffiness in the ears, or giddiness, or a peculiar feeling of resistance to movement, etc. All these sensations soon disappear, however, except when the man is suffering from a cold in the head, in which case the uncomfortable sensations in the ears may persist for some time. The cause of this stuffiness in the ears is that the air pressure on the inside of the drum of the ear, *i.e.*, in the tympanic cavity, is not immediately adjusted to what it is outside, thus causing the drum membrane to bulge inwards and become thereby stretched. By holding the nose and blowing, the sensation is immediately relieved, for by this act the pressure in the tympanic cavity is made equal to that without, through the Eustachian tube, which runs to the cavity from the back of the nasal passages. A cold in the head causes congestion of the lining of the Eustachian tube and thus blocks it, making the adjustment of pressure on the inside of the ear a slower process.

After being for some time in the compressed air there is usually noticed a frequent desire to pass water and sometimes a great drowsiness and several other minor sensations.†

During decompression (especially if rapid) there is usually a sensation of cold (due to the expansion of the air) and some breathlessness, but it is after his exit from the lock that the first real symptoms attack the caissonier. In the severest cases the man suddenly falls unconscious to the ground, his respirations become embarrassed, his heartbeat fluttering, and he may die in a few minutes. In other cases, consciousness is not lost, but the

---

* To those whom it may interest, a full account of the symptoms will be found in the following papers:

1. Paul Bert: "La Pression Barométrique," Paris, 1878.
2. E. H. Snell: "Compressed Air Illness," London, 1896.
3. Heller, Mager, and Von Schrötter: "Luftdruck Erkrankungen," Wien, 1900.
4. Hill and Macleod: "Caisson Illness and Diver's Palsy," *Journal of Hygiene*, Vol. III, p. 407, 1903.

† In subjecting themselves to an air pressure of + 7 atmospheres in an experimental chamber, Hill and Greenwood, after learning how to blow up the ears, felt no discomfort. (See below.)

man suffers from fearful pains, especially in his muscles and joints, distressing breathlessness, paralysis, hemorrhages, cyanosis (blueness), deafness, etc. With proper care he may recover, but his recovery will be tardy, there remaining many "dregs" of the disease: paralysis, incontinence of urine, blindness, deafness, etc.

It should be pointed out here that the severe symptoms are now very rarely seen in caisson workers, although they are quite common amongst deep-sea divers, as, for example, in the sponge and pearl fisheries of Greece and Australia. They are noticed in careless diving where the divers, to get quickly to the boat, screw up the outlet valves in their helmets and in this way fill their suits with air, which carries them suddenly to the surface, where they decompress themselves by opening the valve. Among the Greek divers, Siebe and Gorman, the diving engineers of London, tell us that over a score of men lose their lives every year.

In the less severe cases the symptoms are often long delayed in their appearance. The worker may have returned home feeling perfectly well and may remain so for several hours. Pains in the joints and muscles and ears, giddiness, embarrassed breathing, vomiting, etc., may then occur, being not uncommonly first noticed after the patient has got warm in bed. Of greater or less severity, these symptoms usually disappear after some time, but not in all cases, for here, as in the acute cases, paralysis, deafness, etc., may remain as more or less permanent conditions.

Such is, briefly, a survey of the symptoms of this so-called disease. Having acquainted himself with the exact conditions and symptoms of a disease, the physician next calls in the aid of the scientific investigator to enable him to discover the cause. He knows full well that, having discovered this, it will be an easy matter for him not only to treat the disease, but, more important still, — for prevention is better than cure,— to prevent its recurrence. It is to experimenters such as Pasteur, Koch, Lord Lister, etc., that the medical profession, and consequently humanity at large, owes so much in the prevention of various diseases. Although the discovery of the cause of caisson disease is, when compared with that of anthrax, or sepsis, or tuberculosis, a very simple matter indeed, yet its very simplicity makes it an unusually interesting and profitable study, not only for the medical man, but for every one interested in the progress of scientific knowledge. To engineers it has a further interest in

the practical utility to which they are in a position to place the knowledge.

In investigating the cause of a disease we must first of all examine what structural damage it brings about in the animal body. And so with caisson disease, we find on *post mortem* examination that the chief lesions lie in the viscera and central nervous system (brain and spinal cord). In these locations are found congestion, with occasional hemorrhage, lacerations of the delicate nervous substance of the spinal cord. Sometimes, bubbles of gas are seen in the blood vessels or subcutaneous tissues.

These findings after death led the first investigators of this disease to conclude that its cause lay in the direct effect of the compressed air driving the blood out of the superficial parts of the body into the more deeply situated viscera. To quote A. H. Smith,* one of the chief exponents of this view, " Under high atmospheric pressure the centers will be congested at the expense of the periphery, . . . and . . . firm and compact structures (referring to the brain and spinal cord) will be congested at the expense of those more compressible."

Such a view, however, could not for long hold sway. Not only is it absurd from a physical point of view, but it is inconsistent with the fact that caisson sickness is never manifested while the workman is under the increased pressure. Its exponents were evidently unaware of an experiment conducted as early as 1835 by Poisseuille, who observed the circulation in frogs and young mice placed in a glass chamber and submitted to a pressure of from 2 to 8 atmospheres without the slightest effect. Their conception of the physical nature of the animal body, moreover, was entirely erroneous. They forgot that, physically considered, this consists of an elastic bag filled with fluid,— even the bones are, during life, composed to a considerable extent of water, — the solid parts of the body merely forming a sort of elastic meshwork. When we consider this, then, we see at once that in obedience to well-known laws of hydrostatics the pressure applied to the outside of the body will be instantly transmitted to an equal extent everywhere inside it. The only structure which will show a compression is an air-filled closed cavity, such as the intestines or the tympanic cavity of the ear. In the case of the latter cavity, as already explained, the pressure is adjusted by opening the Eustachian tube. It is inter-

* Dr. Andrew Smith: " Effects of Compressed Air," Detroit, 1886.

esting to note that the compression of the intestinal gases causes the caissonier to tighten his belt.

It was Paul Bert * who, in 1881, first clearly exposed the physical error in the congestion theories, and it is to this celebrated pupil of Claude Bernard that we owe the true explanation of the cause of the symptoms. The investigation first of all taken up by the pathological worker was now handed on to the experimental physiologist, and the remarkable experiments of Paul Bert and his successors leave not the vestige of a doubt as to the true cause of this disease.

Before describing these experiments let me briefly explain the causation. When an animal is introduced into compressed air, the tissue fluids dissolve the air in obedience to Dalton's law of solution of gases in fluids, which states that the amount of gas dissolved in a fluid is proportional to the pressure of the gas surrounding the fluid. Thus, if a fluid dissolve one volume of gas at one atmosphere, it will dissolve two volumes at two atmospheres, and so on. This dissolved air in the blood is quite harmless and the animal in no way suffers. Whenever the pressure of the surrounding air is suddenly lowered, however, as in decompressing quickly, then the dissolved air is thrown out of solution, forming bubbles which stick in the minute blood vessels and block them. In this way the blood cannot flow through its vessels, and the heart, still pumping for some time, causes the obstructed vessels to become engorged and sometimes to burst. Likewise in the other fluids of the body: in the tissue juices air bubbles are liberated and according to their location damage is done to various organs. If, for example, these bubbles form in the vessels or joints or nerves, they will cause the pains above described; if in the spinal cord, paralysis; if in the heart, heart failure; if in the lungs, breathlessness; if in the eyes, blindness, and so on. When decompression is slowly effected then no bubbles appear and consequently no symptoms. The whole mechanism may be well illustrated by a bottle of effervescing water, such as soda water. Such water contains gas in solution under pressure. When the cork is withdrawn, the pressure being suddenly relieved, bubbles of gas appear in the fluid; it effervesces. If, however, a pin hole be made through the cork and the gas be thus allowed to slowly escape, then in the course of time all the dissolved gas will leave the fluid without any bubbles appearing.

From this explanation it is evident that the proper treat-

* *Loc. cit.*

ment of a case of caisson disease is reapplication of the pressure followed by very slow decompression. Medical locks are commonly provided at caisson works for this purpose. By thus reapplying the pressure the bubbles become redissolved. To take the case of the bottle of effervescing water, if, while it is effervescing, the bottle be again corked, the effervescence will at once cease and the water become quiet.

The immediate cause of the symptoms is thus easily explained, but for practical purposes, from the engineer's standpoint, the explanation leaves us uninformed of many fundamental facts. It does not explain why some men should be prone to the condition and others not; it does not explain why long shifts should be a predisposing factor, and so forth. To throw light on these questions, and to fully prove the theory itself, a large series of experiments on animals has been conducted, first of all by Paul Bert, and subsequently by Lorrain Smith, Von Schrötter and Leonard Hill and myself.* I shall now proceed to give you a brief account of the chief of these experiments, and then in conclusion I shall state what laws for prophylaxis can be deduced, both from experiment, and from observation made on the disease itself.

In describing the experiments it will simplify matters to classify them according to the problems they were designed to solve, and the problems which we will consider in this connection are as follows:

Evidence that while in the compressed air there is no change in the circulation or in the other physiological processes of the body.

Evidence that the tissue fluids, when the animal is under pressure, dissolve gas in obedience to Dalton's law.

Evidence that on quick decompression symptoms exactly like those of caisson disease are produced, and that these are due to frothing in the blood and other tissue fluids. On the other hand, slow decompression is never followed by the symptoms.

Evidence that by reapplication of the pressure and subsequent slow decompression the symptoms disappear.

While in compressed air there is no physical change in the circulation or in the other physiological processes of the body. The following experiments by Leonard Hill, F. R. S., and myself prove the truth of this statement.

A frog was placed in a small cylinder closed at the ends by

* For references see p. 1.

removable windows of thick glass and connected with a cylinder of compressed gas (oxygen). A foot of the frog was tied out on a wire frame so as to stretch the web. The expanded web was adjusted so as to lie against one of the windows. A strong arc light was thrown through the chamber, and by applying a microscope to the outside of the window against which the web was stretched we could easily see the blood circulating in the blood vessels. Having studied this for the normal frog, we then quickly raised the pressure in the chamber by turning on the cylinder of compressed gas. Absolutely no change was produced in the circulation of the blood.

Messrs. Siebe and Gorman, the diving engineers of London, constructed for us a pressure chamber large enough for observation on dogs, cats, etc. This chamber was provided with an observation window and illuminated in its interior by electric light. In one case we placed in the chamber an anesthetized rabbit with its carotid artery connected with a manometer and on raising the air pressure in the chamber we saw not the slightest change in the blood pressure.

There can exist no doubt, then, that the old theory of a compressing of blood into the interior of the body from its superficies is wrong.

Regarding the other physiological processes, the fact that we have never seen an animal suffer any symptoms while under the pressure is itself sufficient evidence that there can be little change in those. For example, we have observed a monkey (Rhesus) that was placed in the chamber at a pressure of +7 atmospheres for 4 hr. three or four times a week for a month, and who was as well at the end of his experience as at the beginning. Towards the end of the 4-hr. shift he would often become sleepy. We have besides this observed mice, rats, cats, dogs, rabbits, and birds under pressures running up to 7 atmospheres and never noticed any symptoms.

All these observations on animals may possibly not seem sufficient evidence to prove that *man* shall not suffer when under pressure. Apart from the account given by workmen in caissons, there are, however, experimental observations by L. Hill and M. Greenwood, Jr.,* bearing on this question. These workers had placed at their disposal, by Messrs. Siebe and Gorman, a steel cylinder of 42.2 cu. ft. capacity, fitted up with mattress, blanket,

* L. Hill and M. Greenwood: "Influence of Increased Barometric Pressure on Man." Proceedings of the Royal Society, Series B, Vol. LXXVII, p. 442 (1906).

and pillows, so that a man could adopt a comfortable attitude inside of it. It was also furnished with electric light, telephone, gages, etc., and was connected with a diver's pump. Hill and Greenwood have frequently subjected themselves to increased pressure in this chamber, sometimes, indeed, up to +7 atmospheres, equaling a depth of over 210 ft. of water. Their first experiences under pressure were somewhat distressing on account of the discomfort in the ears, nervousness lest the chamber should burst, and inability to use the lips and tongue in speaking; but after a little practice neither observer found that the compressed air produced any effect on him. He felt perfectly comfortable and active. These experiments have now been repeated many times.

Observations have also been made with the intent of finding out whether the increased pressure causes any change in the chemical processes of the animal body. There are two general methods by which the physiologist determines the nature of the chemical changes in the animal; one is by an analysis of the urine (with consideration of the nature of the diet) and the other is by analyzing the expired air. Paul Bert recorded several observations bearing on this phase of the question, and more recently Leonard Hill and I have considerably extended his observations.

To study the chemical composition of the urine the observations were conducted on three dogs, the animals being compressed to +6 to +7 atmospheres for several hours a day and the urine meanwhile carefully collected and analyzed. Such investigations extended over a week or two. In none of the three dogs was any definite change in the urine noted. This conclusion is contrary to that of Paul Bert, but we have shown elsewhere that his analyses were not of sufficient accuracy.*

Regarding the analysis of the expired air, or, in physiological language, the respiratory exchange, Hill and I have conducted a long series of observations on mice,† rats, and rabbits, and more recently Hill and Greenwood ‡ have extended the observations to man.

In the investigations on lower animals we placed the animal in a steel chamber connected by tubing with a cylinder of compressed air at one end and at the other with a series of weighed

---

* Hill and Macleod: *Journal of Hygiene*, Vol. III, p. 407, 1903.

† Hill and Macleod: *The Journal of Physiology*, Vol. LXXIX, p. 492, 1903.

‡ Hill and Greenwood: *Loc. cit.*, p. 450.

U-tubes, those next the chamber containing pumice stone saturated with concentrated sulphuric acid and the next one soda lime. A constant current of air was kept passing through the chamber and tubes, which carried with it the exhalations of the animal. After the experiment the U-tubes were again weighed, the increase in weight of the sulphuric acid tubes indicating the amount of water given out by the animal, and the increase in weight of the soda lime tubes the amount of carbonic acid. After studying in this way the discharge of water and CO_2 from animals under normal pressure, we increased the pressure by regulating the inflow and outflow of air to the chamber by valves, always seeing that a current continued to pass through the tubes. The results were briefly as follows: At a pressure of +4 atmospheres and upwards, compressed air markedly diminishes the CO_2 output in mice, very greatly lessens the H_2O output, and increases the loss of body heat. This effect on body heat we determined by taking the temperature of the animal before and after being in the chamber.

In a long series of observations we found that different animals show a variable resistance to the compressed air, but the general nature of the result was always the same.

Our next problem was to find out what exactly it is in the compressed air which brings about the result. It might be due to several causes, among which two are of greatest importance, *viz.*, the poisonous effect of the increased amount of oxygen in the compressed air, and the cooling effect of the compressed air. We have investigated each of these factors. Regarding the former, it had already been pointed out by Paul Bert that prolonged exposure to even one atmosphere of pure oxygen slightly lowers the CO_2 output and temperature of mice, both returning to the normal on replacing the oxygen with air. Hill and I have confirmed this.* Now it is evident since air contains one fifth volume of oxygen, that at 5 atmospheres of air (that is to say, +4 atmospheres [+60 lb.]), the air in the chamber will contain one volume of this gas. This biochemical evidence of the toxic effect of oxygen is further confirmed when animals are subjected to higher pressures by very serious effects on the lungs and central nervous system. The effect of compressed oxygen on the lungs was first noticed by Lorrain Smith.† He found that at 170 to 180 per cent. (corresponding to +7 atmospheres air or a

* Hill and Macleod: Proceedings of the Royal Society, Vol. LXX, p. 455.

† Smith, Lorrain: *Journal of Physiology*, Vol. XXII, p. 315 (1898).

depth of 250 ft. of water) the lungs lose the power to actively absorb oxygen, and that after being exposed to such pressures for long periods of time the mice died of pneumonia. Thus, at 180 per cent. atmosphere, O_2, death occurred in 24 hr., and at 300 per cent. atmosphere, in 5 hr. We have repeated these observations of Lorrain Smith with, in general, similar results.

At still higher pressures of oxygen the nervous system becomes involved, producing most violent convulsions, usually resulting in death.

These results would at first sight seem to show that the effect of the compressed air in lowering the CO_2 and H_2O output from the lungs, and the body temperature, is entirely due to its high tension of oxygen, but a more critical examination has convinced us that such is not the case. From the above results we see that whereas at +4 atmospheres air pressure the depression is usually quite marked, it is only very slight in 1 atmosphere oxygen. Furthermore, and this is the important point, as the air pressure is increased above +4 atmospheres the diminution in the excretion of CO_2 and H_2O from the lungs, as well as the fall in body temperature, becomes very marked, much more so than in corresponding pressures of pure oxygen. Thus in +10 atmospheres air the depression is extreme, in +2 atmospheres pure O_2, only moderate. Nevertheless at continued high air pressure the poisonous effect of oxygen manifests itself on the lungs. When the air pressure is raised to +7 atmospheres it takes at least 24 hr. to produce any symptoms of lung affection. For shifts of 4 hr. duration a pressure of even +7 atmospheres (210 ft.) had no effect on the lungs of a monkey who underwent this experience several times a week for a month.

The depressing effect of the compressed air on small animals we have definitely shown to be due to the enormous cooling effect of the compressed air. Under pressure the air becomes saturated with moisture and so wets the fur of the animal and causes exaggerated heat loss. It is obvious that on man such increased heat loss will be of little moment. The greater bulk of his body in relation to his surface area, and the more highly developed power he possesses of regulating his balance of heat production and heat loss, when compared with such an animal as a mouse, will make the cool air have little effect on him.

It should be particularly emphasized here, however, that a partial pressure of oxygen exceeding 2 atmospheres is unsafe. At this pressure both the pulmonic and the nervous symptoms may supervene. Two atmospheres oxygen corresponds to a

pressure of 10 (+9) atmospheres air, or a depth of about 300 ft. Allowing a liberal factor of safety and considering that below the above pressure no untoward results have ever been noted we may state that diving to 210 ft. is permissible. Indeed, our experiments show that with short shifts there cannot probably be any risk in diving to 7 atmospheres, 250 ft.

When the animal is under pressure, the blood and tissue fluids dissolve gas in obedience to Dalton's law.

To study this point, Hill and I placed an anesthetized dog in the large pressure chamber above described and connected the carotid artery by india-rubber tubing with an outlet tube in the chamber. When the valve on this outlet tube was opened, a sample of blood was readily collected, the pressure squeezing it out of the animal. We then estimated the amount of gas dissolved in the blood by means of the apparatus devised for this purpose by Leonard Hill. Our results are given in the following table and will be found more fully reported elsewhere.*

Atmosphere.	Duration of Exposure.	Am't of Gas in 100 gr. of Blood. O_2	CO_2	N	Calculated Amount of N_2 which 100 gr. Blood should Contain if Dalton's Law is Obeyed.
$6\frac{2}{3}$....	30 min.	22.10	37.28	8.41	9.42
	2 hr., 45 min.	25.81	40.66	11.61	9.42
$6\frac{2}{3}$....	1 hr.	14.3	45.7	10.14	9.42
	1 hr., 30 min.	10.56	39.41	12.9	9.42
$5\frac{1}{3}$....	45 min.	14.74	37.7	7.48	7.78
	1 hr.	16.55	39.24	9.27	7.78

Considering in this connection the nitrogen alone, and remembering that in the analysis of the blood an excess of oxygen is a common error, we see that Dalton's law is obeyed. It will further be noted from the table that it does not take very long for the blood to dissolve the requisite amount of gas.

Hill and Greenwood † have more recently investigated this question on themselves, not indeed by analyzing their arterial blood gases, for that would be an impossible experiment on man, but by determining the amount of gas dissolved in the urine. In order to increase the formation of urine they drank large quantities of warm water and then placed themselves in the chamber

* Hill and Macleod: *Journal of Physiology*, Vol. XXIX, p. 382 (1903).

† Hill and Greenwood: Proceedings of the Royal Society, Series B, Vol. LXXIX, p. 21 (1907).

above described, the pressure being raised to a definite amount. When this had been attained, the bladder was emptied and the urine collected in a vessel which was then closed airtight. Another sample of urine was collected 10 min. later, slow decompression was then started, samples of urine being collected every 10 min. during it, and for some time after the pressure had returned to zero. The resulting samples of urine were then analyzed for dissolved gases in the usual manner. Under normal conditions of atmospheric pressure and temperature it was found that 100 cu. cm. urine dissolved 1.4 cu. cm. nitrogen from the air. Under pressure the following table gives the average of the various experiments:

Pressure.	Average Amount of N_2 Found, Per Cent.	N_2 Per Cent. Calculated, Supposing Urine Followed the Pressure.
0 lb.	1.14	1.1
30 lb. for less than 10 min.	1.99	3.3
30 lb. for more than 10 min.	3.32	3.3
45 lb. for less than 10 min.	4.29	4.4
45 lb. for more than 10 min.	4.23	4.4
30 lb. during decompression	3.63	3.3
15 lb. during decompression	2.75	2.2
0 lb. on decompression	1.99	1.1
0 lb. after decompression	1.64	1.1
0 lb. more than 15 min. after decompression	1.13	1.1

Regarding solution of the gas, it is seen that in 10 min. this was attained. This is a surprisingly short time, and in considering the results of the observation it must be remembered that the kidney is a very vascular organ, *i.e.*, richly supplied with blood, and that consequently its tissue fluids, including the urine which it excretes, will come to dissolve the same amount of gas as is in solution in the blood much more quickly than would be the case in less vascular organs or tissues, such as fat, etc. This point is of importance with regard to the question of how long the shifts in compressed air ought to be. In this connection it is of interest to note that Vernon* has found that the fat of mammals dissolves at least five times as much nitrogen as an equal volume of water or blood plasma. This gas-dissolving power of fat explains why gas bubbles are so often formed in the spinal cord and other structures rich in fat when decompression is too rapid.

* Vernon: Proceedings of the Royal Society, Series B, Vol. LXXIX, p. 366.

Evidence that on quick decompression symptoms exactly like those of caisson disease are produced, and that these are due to frothing of the blood and other tissue fluids.

The experiments to prove this fundamental point consisted in placing animals in compressed air for a certain time, and then decompressing rapidly and examining the behavior of the animals. Paul Bert was the first to perform such experiments, all of which, along with many others, have been repeated by Hill and myself.

The following brief outline of the chief of these may be of interest:

1. Two toads were compressed for 1 hour to 20 atmospheres O_2 and rapidly decompressed. The animals went into tetanic spasms and swelled to double their natural size with the gas set free in the tissues. The heart was enormously distended, tense and scarlet in color. On letting out the froth (by puncturing it) the heart began to beat vigorously. (L. Hill.)

2. Rat in 20 atmospheres O_2 for 6 min. Rapid decompression. Respiration almost failed, *tetanic spasms*, paralysis of hind legs, contracted pupils; died in 80 min. Air bubbles were found in the liver, mesenteric vessels, numberless small ones in the mesenteric fat, in the uterus and fœtal membranes (the rat was pregnant). The spleen and intestines were greatly congested. There was almost no blood in the heart. (L. Hill.)

3. A large cat, two half-grown rabbits, two large rats and two white mice were placed in the chamber constructed for us by Messrs. Siebe and Gorman and the air pressure was raised to 105 lb. (+7 atmospheres). A ventilation current was maintained. All the animals appeared, by observing them through the window, to be perfectly normal. At the end of an hour rapid decompression was brought about. The chamber filled with mist owing to the cooling of the expanded air. When the mist cleared we saw that the cat and one rabbit were dead, while the other rabbit was in violent tetanic convulsions. On opening the chamber the rats were found to be dead. The second rabbit died also and the mice alone survived. Emphysema (air bubbles) of all the tissues, and frothing of the blood in the right heart and lungs, were found on examining the animals *post mortem*. In one of the rabbits (an albino) hemorrhage could be seen in the blood vessels of the retina (nervous layer of the eye).

These three experiments, selected from a long series of similar ones, and absolutely typical, prove sufficiently that very rapid decompression means certain death, and that the symp-

toms are exactly those of caisson disease. It might be argued, however, that the length of time taken in decompressing in the experiments is far shorter than that adopted even in the most careless caisson work or in deep-sea diving. I shall, therefore, give examples of experiments where similar symptoms supervened after a decompression which occupied a longer time than that ever taken in decompressing caisson workers.

A Rhesus monkey, a rat and two mice were compressed to +7 atmospheres for 4 hours. The animals seemed untroubled by the pressure. Decompression was started at 4.30 P.M. by opening a small tap in the chamber; the last part of the decompression was hastened, and when, at 5.25, the pressure registered 10 lb. to the square inch, a large valve was opened and the pressure quickly brought to zero. On opening the chamber the monkey and other animals seemed perfectly normal. On removing the monkey from the chamber he struggled to escape, but in the course of a minute or two suddenly became quiet and lay on his side gasping and giving a peculiar cry. He gradually got more and more dyspnoeic (breathless), and his lips, tongue and face markedly cyanotic (blue). Despite careful treatment and artificial respiration, he died in 10 min. after removal from the chamber. On *post mortem* examination it was found that the blood in the heart was frothy and that bubbles of air were present in the mesenteric veins. The decompression, though slow enough to obviate symptoms in the smaller animals, was evidently too rapid for the monkey. It occupied an hour, a period of time never given in caisson work for this purpose.

The tissues of certain of the animals used in the above experiment were examined under the microscope and showed exactly the same hemorrhages and air bubbles that have been observed by pathologists in men dead of caisson disease.

In a case in which another monkey was subjected to +7 atmospheres for 4 hours (2½ hours being taken to decompress) no symptoms were noted, and the experiment was repeated at least fifteen times. Similarly, in other animals slow decompression was never followed by any symptoms. These experiments, then, leave not a particle of doubt that the sole cause of caisson disease is the liberation of bubbles of gas in the tissue fluids.

This brings us to the discussion of perhaps the most important point of all, *viz.*, *how long ought to be taken in the process of decompression in man, and what means may he adopt to prevent the formation of air bubbles?* In the experiment of Hill and Greenwood on themselves, referred to above, a long time was

taken in decompressing; for example, after 54 min. in a pressure rising from 0 to +90 lb., 2 hr. 17 min. were taken in decompression; after +75 lb., 95 min.; after +75 lb., 120 min.; after +75 lb., 105 min. These observers never suffered from other than slight and occasional neuralgic pains (the "bends") and from these only in the first observations, for they soon learned that exercise and massage of the body during decompression entirely obviated the pains.

The object of muscular movement and massage is to assist the circulation of the blood. Its importance will be evident from the following observations: During slow decompression from +75 lb. pressure, Greenwood moved all the limb joints at frequent intervals with the exception of the knees. Subsequently pains and stiffness were detected in the knees and nowhere else. In other cases all the joints were moved, when no after effects of any kind were experienced. Greenwood is a thin man with little subcutaneous fat, so that massage in his case was not necessary. In the case of Hill, who is a large, stout man, on being compressed from +5 atmospheres in 155 minutes, he moved all his joints frequently and on emerging from the chamber felt no discomfort. In the evening, however, pains appeared over the chest, where there was a large amount of subcutaneous fat. These pains were followed by a skin rash and were evidently due to air bubbles. In the fat an excessive amount of gas is dissolved so that it is much more slowly thrown out of solution than in the blood or other tissue fluids. By massaging these parts the circulation of the blood is assisted and the dissolved gas, therefore, carried into the general circulation and got rid of. Hill and Greenwood recommend that all caisson workers while in the decompressing air lock should be instructed to perform muscular movements and practice massage of the parts which they cannot move.

From Hill and Greenwood's observations on the behavior of the gas dissolved in the urine after decompression we see that the last stage of decompression should be very slowly regulated.

When we contrast the experimental results with the periods of decompression employed at some of the chief caisson works we shall see that instead of its being surprising that caisson disease should occur even when moderate care is adopted, it is a wonder that cases are not much more frequent.

The following table from the article of Hill and myself in the *Journal of Hygiene* gives the average time employed in caisson operations.

PERIODS OF SHIFT AND DECOMPRESSION AT CAISSON WORKS.

Atmosphere (maximal).	Length of Shift.	Period of Decompression.	Place.
$4\frac{1}{4}$	4 hr.	30 min.	Chalonnes
2	—	10 sec.	—
$3\frac{1}{2}$	4 hr.	12–15 min.	Vehl
	(Rule often broken by men.)		
$3\frac{1}{2}$	—	20 min.	—
3	8 hr.	4–5 min.	St. Louis
$3\frac{1}{2}$	4 hr.	10 min.	St. Louis
4	3 hr.	18 min.	St. Louis
2–3	8 hr.	4 min.	Blackwall
	(Often shortened to 30 sec. by men.)		

It will be seen at once that the decompression is, in all cases, dangerously short.

It is, of course, evident from our experimental results, as well as from the experience of caissoniers, that in determining how long a time ought to be taken in decompression, consideration should be taken of the length of shift. In low pressures up to above 3 atmospheres the shift may be quite long, for it is probable that within an hour, at least, as much gas will have become absorbed as is going to be. On the other hand, at higher pressures, we must endeavor to prevent the body from absorbing all the gas that it might absorb, and to do this we must shorten the shift.

From a consideration of our experimental results and from a study of the literature bearing on this subject, we would suggest the following times of compression and decompression as safe for different depths:

Atmosphere.	Lb. Pressure.	Shift.	Decompression Period.
+1 to +2	15 to 30	4 hr.	30 min. to 1 hr.
+3 to +4	45 to 60	4 hr.	$1\frac{1}{2}$ min. to 2 hr.
+5	75	1 hr.	$1\frac{1}{2}$ min. to 2 hr.
+6 to 7	90 to 105	30 min. to 1 hr.	2 hr.

It is impossible to give a general figure from which to calculate the proper time for decompression, since the length of shift must be taken into account. In general, however, it can be stated that for pressures up to 3 atmospheres the shift may be 4 hr. and the decompression at least 30 min. an atmosphere. Above 3 atmospheres the shift ought not to be so long and the decompression ought to occupy from 20 min. to 30 min. an atmosphere. Care should always be taken not to hurry the last stages of the decompression. To prevent men breaking the rules, the decompressing lock should be provided with one cock

only, which will allow decompression to take place in the given time. A separate lock should be provided for the rapid passage of material. The chamber should also be kept warm, as in decompressing the expansion of air greatly lowers the temperature.

Evidence that by reapplication of the pressure, followed by slow decompression, the symptoms disappear.

In the experiment in which we observed the circulation in the web of the frog subjected to a high pressure in the small chamber, we noted, as already stated, that the pressure alone produced no change. When, however, we suddenly decompressed by opening a tap in the chamber, a most remarkable change was seen in the circulation. Bubbles of gas, some small, others large, were seen to form in the blood, soon blocking the vessels and in this way entirely stopping the flow of blood. Having observed this we reapplied the pressure, with the result that the bubbles again went into solution in the blood, so that they disappeared, and the blood began to circulate in a perfectly normal fashion. We then slowly decompressed and removed the frog unscathed from the chamber.

In the treatment of caisson symptoms it is necessary in reapplying the pressure that no time be lost after the symptoms appear. The following instructive experiment performed by us in the large chamber above described will make this clear: A large hutch rabbit was kept under a pressure of +7 atmospheres for 4 hours and then was quickly decompressed. In a minute or so, typical decompression convulsions appeared. A cylinder of compressed air was emptied into the chamber and the pressure thus reapplied. The symptoms, however, remained unabated, and the rabbit soon died. It was evident, from the experiment, that for the reapplication of pressure to be of any avail the pressure must be very quickly re-established and no time be given for the air bubbles to tear up and damage permanently the nervous tissues, or to produce stasis of the circulation for a long period. We, therefore, repeated the experiment with the modification that the pressure was more quickly reapplied.

A cat and a hutch rabbit were subjected to an air pressure of +7 atmospheres for 4 hours. Decompression was effected to zero in about 5 sec., and as quickly as the taps could be opened (about 5 sec.) a large cylinder of compressed air was delivered into the chamber, thus raising the pressure to +95 lb. in about 2 min. In this experiment we did not wait for the symptoms before

reapplying the pressure. At the moment of decompression the cat sprang to the window, excited, and soon became entirely paralyzed in the limbs, so that it fell helpless on its side, its head meanwhile showing continuous side-to-side pendulum-like movements. On recompressing, these symptoms gradually disappeared, the head movement being the first to go. The pressure was maintained for 45 min. and then was slowly lowered to zero. The cat and the rabbit (which had shown no symptoms) were found to be perfectly normal when they were removed. There is no doubt, then, that recompression, after rapid decompression, causes re-solution of the gas bubbles in the blood, etc., and can save the life of the animal.

Recompression has been tried at several caisson works, and when intelligently used has been found to yield excellent results. For its application a medical lock is constructed (Hudson tunnel, Blackwall tunnel). The treatment must be applied at once and must be controlled by a medical man. We cannot believe the statement by some engineers that this treatment is of no use. We can only surmise that the treatment has not been adequately adopted.

Such is, in brief, the summary of what seems to me the fundamental experimental work on this question. There are, however, one or two further questions about which, for the sake of completeness, it may be well to say a few words. These are especially with reference to the choice of men for high pressure work and the question of ventilation of the caisson.

The choice of men. Both in deep-sea diving and caisson work the men should be young and in every way healthy, of temperate habits, and with little subcutaneous fat. Pol and Watelle * state that young men of eighteen to twenty-six stand the work best; out of 25 men discharged on account of symptoms, 19 were over forty years old. E. H. Snell † found at the Blackwall tunnel that men below twenty years of age were, with reasonable care, immune to caisson disease. Above forty-five years of age, according to Snell, the work is extremely dangerous. Regarding habit of body, A. Smith compiled the following table from the records at Brooklyn Bridge of men under forty-five.

	Spare.	Medium.	Heavy.
Lost little or no time from sickness	25	14	3
Taken sick	28	22	26
Paralyzed	2	3	8
Died	—	—	3

* *Loc. cit.* † *Loc. cit.*

Why a stout man should be more susceptible than a spare one is made perfectly clear from the experiments of Hill and Greenwood. Snell excluded old and heavy men from the Blackwall tunnel caissons and lost no cases. There is no clear proof that long continuance at the work renders a man immune. Old hands are as susceptible as new ones. No man should be employed who has not been medically examined as to the state of his heart and lungs and blood vessels. The men should be tested at low pressure first, and those who suffer from symptoms should be discharged.

Ventilation. It is well known that, in a confined atmosphere, man sooner or later suffers from the accumulation of poisonous gases. The criterion of this pollution of the atmosphere is the amount of carbonic acid (CO_2) found present. When the percentage of CO_2 in the air rises above 0.1 per cent., evil effects are common.* Now under pressure it is evident that such a gas will be still more dangerous. As a matter of fact, E. H. Snell reports that an "increase of CO_2 from 0.04 per cent. to 0.1 per cent. at 30-lb. pressure is the forerunner of much illness." He found that by free ventilation of the caisson, so as to remove this CO_2, the illness dropped from seven cases a day to one case in two days. His very striking results prompted Snell to suggest that caisson disease might actually be due to the setting free of CO_2 in the body during decompression. Such a conclusion is, however, undoubtedly wrong, as is proven by an analysis of the air set free in the tissues in caisson disease, which shows it composed mainly of nitrogen. That a percentage of 0.62 per cent. CO_2 in the compressed air (+31 lb.) does not produce any untoward results was proven by Hill and Greenwood in the experiment already described. Nevertheless, ventilation is a matter which should be carefully provided for, for otherwise the CO_2 and other poisonous constituents of polluted air will have their usual depressing effects on the workmen and render them more prone to suffer from decompression symptoms. The average rate of ventilation should be between 8 000 and 12 000 cu. ft. per man per hour.

The nature of the soil has also an influence in predisposing to caisson disease. It is seen distinctly by Hunter at the Forth Bridge caissons; when soft wet silt was being removed or when concreting was going on illnesses were very frequent. In working

* It should be clearly understood that these evil effects are not due to the carbonic acid itself, but to some other toxic property which the CO_2 content seems to run parallel with, and is, therefore, a measure for.

on the new water intake in Cleveland it was the impression of the medical man in charge that the air in the caissons sometimes became polluted with gases from the earth and that then sickness was common. That may undoubtedly be true, for such gases as sulphureted hydrogen will be more toxic under pressure. Decomposing organic matter should, of course, be removed and earth pails should be provided for the workmen.

As a result of the foregoing investigations and observations we may conclude that caisson work, even to a depth of over 200 ft., is undoubtedly quite safe, provided decompression be slow enough and the other conditions indicated in this article are adhered to. And deep-sea diving, in short shifts, to even greater depths, is unquestionably quite safe. The responsibility of those who allow short decompression periods in caisson works is clear; every death or case of paralysis from air embolism must be set down to the negligence of the contractor.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE TUNNEL AND RIVER SHAFT OF THE DETROIT WATER WORKS.

By James Ritchie, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, June 11, 1907.]

During a part of the years 1904 and 1905 the writer had charge of the construction of the tunnel and river shaft of the Detroit water works, representing the contractors, The C. H. Fath & Son Construction Company of Cleveland. The work was designed and the construction superintended by Mr. C. W. Hubbell, chief engineer of the Detroit waterworks.

Before making a contract for this work the city of Detroit had built a tunnel from the pumping station to a point near the bank of the Detroit River, a distance of about 1 000 ft., and had constructed a gate chamber and a shore shaft with 50 ft. of river tunnel. This work was done with their own men by day labor and without the use of compressed air. The shore tunnel was 10 ft. inside diameter and was placed with its axis at a distance of 26 ft. below the surface of the ground. The shore shaft had an inside diameter of 10 ft. and a total depth below the surface of the ground of 78 ft., 6½ in. The axis of the river tunnel was at a distance of 69 ft. below the surface of the ground, or 63 ft. below the surface of the water in the Detroit River. The inside diameter of the river tunnel was 10 ft., and the tunnel was constructed of four rings of shale brick laid in Portland cement mortar. The diameter of the excavation was 13 ft. After completing the first 50 ft. of the river tunnel, the city put in a timber bulkhead and prepared to let a contract for the rest of the tunnel, the river shaft and the intake crib and crib house. The latter items, namely the crib and crib house, were constructed by the W. J. Gawne Company of Cleveland, and do not enter into this discussion.

The contract for the river tunnel and shaft covered 3 185 ft. of tunnel from the end of the 50 ft. built by the city to a point 75 ft. beyond the center of the intake crib, and a river shaft of 10 ft. inside diameter placed at the center of the crib. The end of the tunnel was finished by two bulkheads 25 ft. apart, to

permit of a second crib and shaft being constructed should it be determined to extend the tunnel.

The contracts were awarded April 8, 1904, and provided for the completion of the tunnel and river shaft within eighteen months, or on October 7, 1905, and for the completion of the crib ready for sinking the river shaft within ten months, or on February 7, 1905. Six months were then to be allowed the contractor to complete the crib and crib house after the contractor for the river shaft had completed his work on the crib.

Work was commenced on the ground at the shore shaft on May 1, 1904, and consisted of setting up the machinery, building engine and boiler house, cement shed and offices, installing the elevator supports and preparing for the work of construction while awaiting the arrival of the materials. The power plant consisted of two boilers, one Ingersoll and one Rand air compressor, each 18 by 24 in., one electric generator and engine for operating same, one elevator hoisting engine, two drainage pumps for removing water from the tunnel and one boiler feed pump. The only part of the plant not in duplicate was the electric lighting, and to provide for emergencies the city lighting plant was connected to our tunnel line by a special switch.

On June 14, 1904, we commenced laying brick, and continued without using compressed air until we had completed about 40 ft., when work was stopped in order to install the air locks. These were two in number, the working lock being 5.5 ft. in diameter and 22 ft. long, set on the bottom of the tunnel and enclosed in brickwork and cement, and the emergency lock above the working lock, to be used in case of accident. The emergency lock was at all times open to the tunnel, so that if the working lock were closed the men could escape any danger by entering the upper lock, closing the door and locking out towards the shore shaft. Underneath the working lock was a 6-in. iron pipe for blowing off the tunnel, provided with a valve on the atmosphere end, and above the lock was a pressure regulating pipe with a safety valve on the atmosphere end, by which the air in the tunnel could be ventilated by raising the pressure above that at which the safety valve was set. Compressed air was furnished to the face of the work through a 5-in. pipe, which was carried along as the work progressed, and the end of which was at all times within 50 ft. of the working face. Water was carried to the face through a 2-in. pipe and kept close enough to the work to supply the mortar boxes through 25 ft. of hose. Electric light wires and telephone wires at all times extended to the face and

maintained light and communication. The telephone gave us the most trouble, as the instruments could not stand the atmospheric conditions for any great time without repair, but they were well worth any trouble that they caused us.

After the air locks were in position and found to stand the pressure, work was continued excavating and bricking in without serious delay, and the only stops made were on Sundays and holidays. Each Sunday the tunnel was thoroughly cleaned and ventilated, wires overhauled, telephone adjusted and other necessary work on the plant performed, ready for the night shift to go on at 11 o'clock. There were two shifts of miners, one going on at 11 P.M. and the second at 7 A.M. The bricklayers went on at 3 P.M. and bricked up what had been excavated by the mining shifts. For about 1 000 ft. after the air locks were placed, the pressure was 8 to 10 lb.; for the second 1 000 ft. it ran from 10 to 20 lb., and for the rest of the tunnel from 20 to 27 lb. At one point where bad ground was encountered, the pressure for about 12 ft. of working distance was 37 lb. The tunnel was completed as far as the location of the river shaft, and the sump under same was then built, after which the remaining 75 ft. of tunnel and the two end bulkheads were constructed. This work was completed on the fourth day of April, 1905, and work was commenced on the river shaft at the crib. The entire time occupied in constructing the tunnel was $9\frac{1}{2}$ months from the first laying of brick, or an average of about 335 ft. per month; but from June 14 to August 1, 1904, we only built 200 ft., being delayed by putting in the air locks and scarcity of brick, the latter coming very slowly at first. In the month of January, 1905, we built 454 ft., 4 in., during which we reached our maximum of one day's work, namely, 21 ft. 2 in., on January 23; 20 ft. 3 in., on January 16; and an even 20 ft. on January 9. Our average during the month of January was 17 ft. 6. in., per day.

The methods of carrying on the work are probably familiar to most of you, but to some they may be new. The mining shifts consisted of one foreman, four miners and six muckers in each shift, also two drivers and one lock tender.

The first mining shift excavated the top half of the tunnel to such distance from the end of the brickwork as the foreman considered could be bricked up in 8 hours, and then took out as much of the bottom as they could in the remainder of their shift. Before commencing their excavation they had to strike the centers and put in the floor and track through the section of tunnel completed by the last shift of bricklayers.

The second mining shift completed the bottom and trimmed the circle and set in place the form for the invert. The reason that it requires more time to do the second half is on account of the men having to lift a large part of the material from three to five feet to place in the cars.

The bricklaying shift consisted of four bricklayers, six to eight helpers, two drivers and one lock tender. The number of brick to the foot being about 825, it will be seen that our average for the month of January of 17.5 ft. meant the laying of about 14 440 brick in 8 hours, or 3 610 brick by each man. This means from 7 to 8 brick per man per minute, and when it is remembered that the keying up of the arch can only be done by one man, and that it ordinarily requires from 45 minutes to one hour to key up, it will be seen that in laying the bottom a much faster rate must be kept up. Besides this the centers have to be set requiring from 20 to 30 minutes, which again operates as a delay. The maximum day's work of 21 ft. 2 in. was laid up by the bricklayers in 9 hours, and required 17 464 brick, or an average per man of 4 366.

The men outside the air lock were divided into two shifts of twelve hours. The day shift consisted of one engineer, one elevator man, one driver, and from two to four laborers. The night shift consisted of one engineer, one fireman, one driver and two laborers. The arrangement was as above until we found it necessary to make three shifts on top, leaving only the engineer, fireman and elevator man on twelve-hour shifts.

Mules were used for hauling the excavated material out of the tunnel to the air lock, from which it was taken on the elevator to the surface and again hauled by mules out on the dump. The month in which we made the best record was full of snow and sleet storms which impeded us in handling the material on the dump, and also in delivering materials into the tunnel. The latter work was done in the same manner as the removing of the earth, namely, by means of mules. The cars used in hauling earth were so made that the sides and ends being removed they were suitable for hauling brick. Also there were boxes provided in which the cement and sand were mixed dry and thus sent into the tunnel on the cars, the mortar being wet and mixed in boxes at the face of the work. The mules changed shifts with the men, and went in and came out after a few trials as easily as any one. After one mule was killed by falling down the shaft, bars were put up to prevent such accidents, and the mules rode up and down like old miners. One mule only was obstinate as to going

into the tunnel, and when he was once induced to go in, the air seemed to intoxicate him, and he ran down the tunnel and drove the men to the furthest limits, winning in the first round. This, together with his power of striking a blow with his feet, caused him to be christened " Terry McGovern," and he was used on top in future to haul out on the dump. The lintels over the shaft-house doors showed many marks of his hoofs, and his drivers were kept busy dodging him.

The only accidents that occurred in connection with the tunnel were two in number, one being when a driver fell and had his leg broken under a car, and the other when a laborer on top had two fingers crushed under the side of a car. Several men were affected by the bends, but none very seriously. The company provided facilities for hot baths for the men at the power house, also for coffee without limit. Medical attendance and examination of the air were also provided for. Every man who worked in compressed air had to be examined before he was employed to see that he was in a suitable physical condition to work in the tunnel.

Preliminary work on the river shaft was commenced on March 16, 1905, by taking tools and materials out to the crib, erecting derricks and setting up engines and boilers. The shaft was designed to be built inside of a steel cylinder having a diameter of 14 ft. at the bottom, with a cutting edge extending 3 ft. below the curb which held the brickwork. This cylinder was to be sunk to the bottom of the river through an opening in the crib, and then to be sunk through about 26 ft. of earth to the top of the tunnel. Guide timbers were placed so as to keep this cylinder in a vertical position, the cylinder was then placed on a raft inside the crib and a watertight floor put in under the curb.

The raft was so constructed that it could be removed when the shaft had nearly reached the bottom of the crib by releasing the lines on one end and pulling the timbers out at the other. To prevent accidents, the lines holding the raft were attached to the heavy cross timbers of the crib at the top so as to support the shaft in case it leaked enough of water to overcome its buoyancy. Also a pulsometer was placed inside and hung from the derrick, steam for same being furnished through a pipe from the auxiliary boiler with hose connection. The steel shaft was made in sections and riveted together on the crib as the cylinder was sunk. The brickwork was started on the curb and was successfully built up for a height of about 16 ft., when the shaft was found

to be so close to the bottom that the raft had to be removed in order to permit the shaft to enter the opening left for it in the bottom of the crib. With misplaced confidence in the pulsometer and the night watchmen, the shaft was left over night; the pulsometer acted badly, the watchmen thought they knew how to correct it, did not blow the whistle for assistance as they should, and neglected to use the buckets to bail out the shaft, which would have saved it, and the shaft filled with water and sank about four ft. into the bottom of the river. It was in its proper location, however, and work was at once commenced to lower the water around it so that the steel cylinder could be extended by riveting on the top section. Several attempts to do this were unsuccessful, and finally the ports through which water entered the crib were blanketed and the inner chamber of the crib was pumped down low enough to permit the riveting to be done, after which it was easy to pump out the shaft. The watertight floor was then removed and the brickwork continued to the top of the lower cylinder. As the brickwork was built up, the shaft kept sinking into the clay, which was carefully excavated so as to keep the shaft plumb, and there was so little resistance by friction that without any external loading the shaft sank to the top of the tunnel, landing almost exactly in its proper location. The above described accident delayed the work about 30 days, namely, from April 28 to May 25. The shaft was completed, including the underpinning, on June 19.

Meanwhile, from April 5 to May 11 and from June 14 to July 1, men were at work scraping and washing the tunnel, finishing by cleaning the shaft. The air locks were removed, buildings and plant were shipped away, the surface of the dump was graded and other necessary work was done. The actual completion and acceptance of the tunnel and river shaft covered by the contract were made on July 5, 1905, being 95 days before the date set in the contract.

A short time before the tunnel was completed a pipe was driven at the edge of the crib on the engineer's center line to a depth such that it would show in the tunnel when we reached that distance, and it was duly encountered about one foot to the left of the center of the work. From this point we deflected the tunnel so as to bring the shaft connection in its proper location under the center of the crib.

In the month of December, 1904, we had our only difficulty in the work, having encountered a sand pocket on the night of the 16th. This was the only place in the tunnel where the roof

required timbering, and was the cause of the increase of pressure to 37 lb. for three days, after which we returned to the normal pressure.

Previous to the letting of the contract, the engineers had taken borings for the entire length of the work, and our findings corresponded exactly with their reports, the material being a stiff blue clay through the entire length of the tunnel, except the sand pocket previously mentioned. This material was of such a character that semi-circular knives were used to cut it out

---

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1908, for publication in a subsequent number of the JOURNAL.]

STREET ENGINEERING.

By Rutger B. Green, Member of the Detroit Engineering Society.

[Read before the Society, May 24, 1907.]

Let us take a 320-ft. block on a 66-ft. street in some older portion of the average American city and go back to the time when the owners of the adjacent property laid out the street and platted their land into 40-ft. lots.

The amount of thought given to the design of the street was evidently to allow about 44 ft. for the roadway and 11 ft. on each side for sidewalks and tree space, the sidewalk usually taking the 6 ft. next to the fence.

City water was soon needed, to supply which a 4-in. or 6-in. main was laid through the street somewhere near its center and separate lateral service pipes laid to each house supplied. The same was done when sewerage and gas were needed, so that to supply each of the 40-ft. lots on each side of the street with water, sewer and gas required three trenches the length of the block and three trenches across the street every 40 ft. Probably before all of these house services were put in, the street was paved; and services put in after that had to cut the pavement to connect with the mains. If telephone conduits were laid through the street, the pavement had to be cut and replaced by a patch. If steam heating conduits were laid, the pavement was cut to pieces again; and now, whenever sewer, water, gas, telephone or stream conduits need any minor repairs or additions, the pavement is cut up and patched, — poorly patched as a rule. Pneumatic tubes and high pressure gas mains may come later and possibly a subway, which latter would require every foot of piping in the street to be relaid.

The expense of cutting these pavements and the botch patching that usually marks the attempt to replace a pavement over a new trench, suggests that our street pipe engineering is still of what might be called the stone age, or cobble-stone age, more strictly speaking. It did not cost much to tear up and replace cobble-stones laid on a sand foundation, and the concrete foundation that brick and asphalt call for is hardly thirty years old.

To attempt now to remodel the present systems of piping in any down-town paved street might be a greater expense than to put up with the present haphazard arrangement, although a mere pipe gallery in front of a modern office building seems an infinitesimal addition to the cost of the building. It does seem possible, however, to start our new streets with a view to more systematic arrangement for probable future needs, to clean up the rubbish pile by beginning at the outer edge.

Consider, for instance, the water supply of the 320-ft. block having a 66-ft. street. If we have one main somewhere in the middle of the street and run taps to each of the 8 lots on each side, we have 320 ft. of 6-in. cast-iron pipe laid by a contractor in one job with cheap labor, and 528 ft. of lateral service pipe laid by plumbers at different times and different costs, — very different just at present, even when they tunnel a pavement. Suppose, now, that instead of one 6-in. main in the middle of the street we have two 4-in. mains, one at each edge of the street. Then we have the water at the street line for every lot at the expense of only 640 ft. of 4-in. cast-iron pipe laid all at once at contract rates.

Those who prefer algebra will find that if

B = Block length.
S = Street width.
1 = Lot width.

Then $\frac{B}{1}$ = number of lots on each side of the street.

$2B$ = length of trenching where pipes are laid on each side of the street.

$B+\frac{BS}{1}$ = length of trenching with one main down the center of the street and laterals to each lot.

Equating $2B = B+\frac{BS}{1}$.

This is true only when S is no greater than 1, which is rather rare with city lots, showing that under ordinary circumstances the two side mains are the cheaper. This considers trenching length alone. The great advantage of having two mains and no lateral, of course, comes in not having to pay plumbers' prices for the laterals and having no pavements to tear up. There seems to be no good reason why the property owner should not have water, sewerage, gas, etc., delivered to him at the lot line instead of having to dig way out into public property for them.

It is true that the space at the side of the street is used

more or less for store areas. It is city property, however, and should be governed by the city needs. There should not be any great objection to moving the pipes out into the street to the edge of an area, if necessary, provided the area builders pay the cost, which would be a very small increase to the cost of business blocks. When stores come, trees usually go; if the area needs the pipes' space, let the pipes have the tree space. Trees seem like railroads, by the way; we need them badly, but have evidently got to insist on municipal ownership, or government control including regulation of roots.

Where the system of alleys prevails, piping may often be laid through them, the economy depending upon the depth of the block, the fact that plumbing usually centers at the rear of houses helping somewhat.

As large trunk mains are generally laid once and for all on special grades and require few repairs, it would probably be cheaper to lay the very large ones near the middle of the street in addition to having the house mains on each side of the street. It might tend to economical uniformity in piping if the four sides of a block were considered a unit, to be served by small pipe fed from the trunk mains. There seems to be room for a distribution unit intermediate between our present house connections and street mains. It would seem that if a $\frac{5}{8}$-in. water connection or 4-in. soil pipe does for a single house, that a 3-in. or 4-in. water pipe and a 6-in. or 8-in. sewer should take care of one or two city blocks, and perhaps a 2-in. for one block if there is sediment in the water. House connections could be made to the intermediate units, which would be laid at the street edge and be connected up to the large supply mains at every block or two, according as the territory is built up.

There should be state laws governing the suburbs of large cities, so that when annexation is probable, piping laid in the suburbs before annexation will conform to city systems after becoming a part of the latter. There should also be city laws putting the control of all street piping, etc., under the city engineer, so that private companies having franchises for undei-ground work in city streets can be properly controlled and their piping made to conform to the general good of the city.

Now that the cement sidewalk has become the standard, it would seem best for the city to contract for it, blocks at a time, just as the main paving of a street is now done.

There might also be less trouble in getting sites for garbage disposal plants if householders were required to press and dry

kitchen refuse for city collection, thus getting rid of the dripping swill barrel and wagon.

It is the writer's belief that street design is a subject that might well be considered by a special committee of any or all our engineering societies. American city engineers are too subject to political caprice to have time to work out such problems, but it seems to be only reasonable that such a special committee could recommend a street section or sections, quoting which city engineers all over the country could apply for authority to lay out new street work with reasonable assurance that their work would be right, whether the street remained a residence one, or gradually was taken up by business. Certainly, the present indiscriminate and perpetual tearing up of expensive pavements is no more creditable to the engineering profession than tearing a house to pieces to get at the plumbing was to architects until they studied out their present accessible plumbing methods. Street piping is merely plumbing of larger sizes and could easily be made accessible, if not in the older streets, then certainly in new streets, and the rate at which our cities are growing means that, immense as the number of new streets is now, it will be still greater as each successive year rolls by.

DISCUSSION.

Mr. Mattson. — Pingree, a number of years ago, endeavored to bring about a better system of pipes in the city, but owing to inaction on the part of the council, etc., his ideas were never carried out.

Mr. Parks. — I cannot see just why lot owner should build subway to get area. Let the subway be built by the city or some one person and then be owned by him. Lease it to those who want to use same.

Mr. Douglas. — I believe with Mr. Green that something ought to be done in the matter of pipe systems through streets. His system, I think, is a very good one, and ultimately cheaper than the present method.

Mr. Lane. — I think it should be attacked by the board of public works, not only in the outlying districts, but in the down-town section. Lot owners would know just where each pipe is by referring to standard design, thus saving unnecessary digging to find pipes.

Mr. Lang. — What would be done in case of a broken water main, or gas main? Would it not cause a great deal of trouble on account of the close proximity of the other pipes?

Mr. Mattson. — There could not possibly be any more trouble, sir, in the proposed system, than is now the case should a water main break or a gas main break. I think the Association should look into the system of piping through streets in order to determine its value. The sidewalk system suggested by Mr. Green, namely, to have whole blocks laid by the city at one time, is a very good one. I would also suggest that sidewalk builders use stronger cement.

Mr. Douglas. — Sidewalks really are nothing more or less than pavements.

Mr. Parks. — When in New York City I had opportunity of seeing the new subway built, and I have never seen such a mess of tangled pipes before in all my life, showing conclusively that such a system as Mr. Green suggests is a long-felt want.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1908, for publication in a subsequent number of the Journal.]

DISCUSSION ON MR. FULLER'S PAPER, SEWAGE PURIFICATION TESTS AT COLUMBUS, OHIO.

(Vol. XXXIX, page 67, August, 1907.)

Mr. George A. Johnson. — A long professional engagement abroad made it necessary for the writer to leave America immediately after submitting the report on the tests at Columbus. In view of this fact, and for numerous other reasons, it was distinctly fortunate that the task of reviewing the results obtained during these tests, and of comparing them with experiences elsewhere, could be taken up before this Society by Mr. Fuller, to whom the writer owes an expression of heartiest thanks.

In the discussion of this paper (pp. 122–3–4), two points are raised upon which the writer desires to say a word. These points refer to (*a*) the removal of bacteria and total suspended matter in sedimentation and septic tanks; and (*b*) to the removal of B. coli in coarse-grain filters. Doubt is expressed as to the soundness of Mr. Fuller's statements that the removal of bacteria in sedimentation or septic tanks approximates that of the total suspended matter; and that the removal of B. coli in coarse-grain filters is, in general, proportional to the removal of the total bacteria. Regarding these points the report on the tests states that "in general, the removal of bacteria by plain sedimentation approaches that of the total suspended matter" (p. 98); "the few local data available upon this point show that under normal conditions colon bacilli are removed by contact filters substantially in proportion to the removal of total bacteria" (p. 246); "the results of analysis for the numbers of B. coli of four samples of the influents and effluents of certain sprinkling filters indicated that these organisms are somewhat more thoroughly removed than is the case of the total numbers of bacteria" (p. 299).

To the writer it does not appear that the criticism offered on these points is well founded. It is true that at Columbus the growth of bacteria in the sedimentation and septic tanks obscured the true removal of bacteria. It is equally true that the number of analyses made for B. coli in the influents and effluents of the various coarse-grain filters was small. It must be remembered, however, that such samples as were analyzed were col-

tected with great care in order that the results might represent average conditions, and that the results were obtained by the most thorough determinative tests, and not by the much less accurate and far more unreliable presumptive test by means of which the contrary results recorded in the discussion were obtained.

Experience in the subsidence in water of suspended matters, including bacteria, has shown in most cases that the removal of bacteria is, in a general way, proportional to the removal of the total suspended matter. There can be no doubt that the removal of B. coli in coarse-grain filters is approximately proportional to the removal of the total bacteria. Such filters certainly do not exert a selective action in removing more of one species than of another. One really requires no analytical data to satisfy him that this must be so, and it is a fact that the published evidence all, or practically all, leads to the same conclusion. If there are cases where it does not, it appears to the writer that the fault must lie with the manner in which the samples are collected and the methods of analysis.

Mr. Fuller's review of the whole matter is, in the writer's opinion, in all ways admirable, and his statements are so much in accord with those of the writer on the majority of the points discussed that further specific reference to the paper appears unnecessary except to commend its thoroughness and consistency.

During the writer's travels last year in the Orient and in Europe an opportunity was offered to make a study at close range of matters relating to municipal sanitation, especially with reference to water purification and sewage disposal. It may be that a few notes in this connection will be of interest.

There can be no question that the art of sewage disposal is advancing rapidly in America, England and Germany. Although the universal panacea, the discovery of which has been announced so many times during the past three decades, has yet to be, but probably never will be, found, studies made in recent years by boards of health, municipalities and educational institutions in this country, by the local government board and various municipal boards in England, and by the German and French governments, have done untold good in the effort to solve a problem which as much if not more than any other has to do with the health of the public at large.

In the far eastern countries the solution of this problem cannot even be said to be in its infancy. Methods of disposal of municipal wastes are still of the most elementary kind. In

Japan, where there are next to no fields suitable for grazing purposes on account of the prevalence of bamboo grass, the number of animals is exceedingly small. Natural fertilizers are, therefore, unavailable from this source, and hence, every ounce of human excrement is carefully preserved. This is collected by contractors and sold to farmers at so much per bucket. The farmers store the fresh and semi-liquid material in small tanks and from these draw their supply for distribution over their fields. The odors which arise from these tanks, in which the crude human excrement is stored in highly concentrated form, are particularly offensive for distances as great as half a mile.

Not a little has been said about this method of sewage disposal which appeals to every casual observer as an exceedingly unsanitary procedure. Foreigners hesitate, if not actually refuse, to eat uncooked vegetables coming from such fields. The writer has personally inspected many acres of Japanese farm lands and can say that there is no doubt about the excreta, as applied, getting on to the growing vegetables as well as on to the ground in which they are growing. He was assured by various engineers, however, that the length of stay of the excreta in the storage tanks had everything to do with the destruction of disease germs, and that as applied to the fields it was as nearly as possible innocuous to health. To the writer, however, it appears to be an excellent field for special research, and in his opinion, were the custom done away with of using in this way raw, or nearly raw, excreta of human origin as fertilizer, there would undoubtedly result a sharp diminution of the high typhoid death-rate existing at present in the case of so many Japanese cities. Aside from the pollution of vegetables, it is obvious that a not inconsiderable amount of dangerous polluting matter is washed from these fields into the rivers at time of rains.

In China, except in the coast cities, which are under the control of foreign governments, no advance of a marked nature has been made since the earliest times. The odor of Canton is well known to the traveler, as it well may be. One can smell Canton before it comes within the range of vision, not wholly, it must be admitted, because of the improper disposal of sewage. All over China sewage now as ever goes untreated on to the fields or into the rivers. Human life is not held at a premium in that country, and those possessing the power to exert a bettering influence in the sanitary disposal of sewage evidently look at the matter in a philosophico-fatalistic way, and let things take their unobstructed course.

Even in Shanghai, one of the most beautiful cities of the East, the conditions in the foreign concessions do not in all ways approach the ideal. When driving along the beautiful Bubbling Well Road in Shanghai, on which there are scores of palaces, the writer recalls distinctly seeing stagnant pools of house drainage in the very back yards of some of the most splendid residences. Hong Kong, happily, is located on the steep slopes of a hill, and the opportunities for natural drainage into the harbor are all that could be desired.

In India, something has been done, but there remains much to do. Quite recently an excellent piece of work in Bengal has been completed by Dr. Gilbert J. Fowler. The results of this work have recently been published.

Here, as in all these eastern countries, the sanitarian has to cope with ignorance, religious bigotries, or at the very least a sublime indifference. The waters of the Ganges and its main tributaries, for example, are not what could exactly be called potable, as the extensive water filtration works of the city of Calcutta bear witness. The majority of the natives of the poorer class are sublimely indifferent to the fact, however, and a familiar daily sight at the bathing ghats on the Ganges is to see hundreds of natives performing their ablutions together, included in which operation is a very thorough rinsing out of the mouth with the water in which the multitude is bathing. Not satisfied with this, the bather on departing takes away with him a vessel of the same water for future use. The vessel is usually of copper or brass, so if there is germicidal virtue in copper receptacles, it may be that the otherwise almost inevitably evil consequences are defeated in some instances in this way.

More or less similar conditions are found at Cairo, where the water supply is drawn from a series of wells along the banks of the Nile. Native water venders, however, may always be seen on the banks of the river within the city, filling their goat skins with river water for the benefit of the poorer classes, or to be made into the popular "limonade" so picturesquely distributed, two glasses for a piaster, about the city. This water is not immaculate as regards purity, as may be inferred.

At present Cairo has no sewers, mainly because it hardly ever rains there, but recently Mr. James, one time municipal engineer at Bombay, and the author of several engineering works, has been retained by the city to lay out a complete system of sewerage. It is understood that purification works are to be included in this system.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXIX. DECEMBER, 1907. NO. 6.

WATERPROOF ENGINEERING.

BY EDWARD W. DEKNIGHT, PRESIDENT HYDREX FELT AND ENGINEERING CO.

[Read before the Boston Society of Civil Engineers, October 16, 1907.]

IT is one thing to build a structure and another thing to make it sound and safe. "Waterproof Engineering" means the sanitariness or healthfulness, the soundness, the safety, the preservation and the durability of structures. It means the fighting of moisture.

Waterproof engineering is based on three fundamental principles:

First. Design.

Second. Method and materials.

Third. Application.

The general subject is too broad to be covered in one evening's discussion. This paper will, therefore, treat only of the second and third principles, viz., "Method and Materials" and "Application."

All efforts in the waterproofing of structural work are divided into two main, totally divergent lines, *i. e.*,

First. Treating concrete to make it, in itself, impermeable.

Second. Protecting concrete or masonry with something *apart* therefrom, to waterproof it.

In other words, Shall water reach the concrete or shall it not reach the concrete? The real point at issue, therefore, is one of method, which must be first settled before we can intelligently discuss the question of materials. First, therefore,

determine the method, and the production of the proper materials will settle itself. We will consider the two above-described systems separately.

1. TREATING CONCRETE TO MAKE IT, IN ITSELF, IMPERMEABLE.

Treating concrete to make it in itself impermeable rests upon two methods:

First. Mixing certain chemicals with the concrete to make the concrete, in itself, impermeable.

Second. Applying a cement plaster or wash on the concrete to harden its surface.

The ingredients generally used are lime, silicate, soda, lye, soap, alum, etc.

One of the present chief difficulties in concrete work is to obtain concrete properly mixed in the field. This difficulty, instead of being lessened, will be greatly augmented by the mixing of chemicals with the cement, with the idea of making the concrete watertight. Certainly, to obtain a concrete so perfect as to be perfectly watertight will be a much more difficult thing than to obtain ordinarily sound concrete. In either case there will always exist zones weak in quality and density. There is also the added danger of the uncertain effect the addition of the chemicals will, in time, have upon the tenacity and the durability of the concrete itself, and especially upon the embedded steel. This is all experimental, and not tried and tested, waterproofing.

The objections to the second method, *i. e.*, applying a cement plaster or wash to the surface of the concrete, are too numerous to mention here. It is poor judgment to depend upon but one layer of any single thing, which in this case is an inelastic cement plaster or a thin, almost imperceptible, wash, as the sole waterproof protection of any structure. This, aside from any consideration of the splitting or cracking of the cement plaster, or that but one infinitesimal pore imperfectly closed, by permitting the entrance of water, which would soon spread, would make valueless the balance of the washed surface. Such treatment is not even consistent with the doctrine of *similia similibus curantur*, because we are not curing like with like, but adding a bad thing to a bad thing.

There is a fine distinction between testing concrete for strength and testing it for watertightness. The difficulty is that these two principles are confounded by experimenters in attempting to make concrete in itself watertight.

Assume for the moment that concrete *per se* may be made impermeable. If this impermeability will not prevent cracking, and as cracking will destroy the value of impermeability, why attempt to make concrete impermeable? Granted that even limited impermeability, as it were, is a desirable quality, is there not needed, however, something additional for dependable and perfect waterproofness for general conditions and practical work? There is no more important problem before the engineering and architectural professions than this one, — Whether concrete can, in itself, be made watertight.

Waterproofness is not what it is to-day, but years hence. Because a briquette, or cube, or box of specially-treated concrete remains watertight in or out of a laboratory for one or twelve months is no warranty that concrete can be made permanently watertight for practical purposes. Assuming even that there can be had concrete in monolithic form so perfect in texture and mixture as the specially-prepared laboratory sample, masses of concrete in the open are subject to conditions, especially in this latitude, impossible of ascertainment and test in a laboratory sample: to extremes of heat and cold, to settlement, to contraction and expansion, to earth tremors, both natural and artificial, — resulting in fractures, the opening of pores, etc., a process which certainly does not decrease with the advance of years. Water will come through concrete in time. It will take longer to work through so-called watertight concrete, but it will eventually come through it. Otherwise it would be contrary to the law of physics and nature. The same principle applies, in greater course, to cement plaster and hardening compounds for the surface.

We have seen water drawn up, through capillarity, 15 or 20 ft. by concrete. We have also seen water percolate through concrete over 20 ft. thick. It may take two or three years to do so; meanwhile, the assumption is that the concrete is fairly watertight. When the concrete thus becomes damp, wet, and saturated, it is almost impossible to eradicate the moisture. If the moisture freezes, expanding one tenth its volume in so doing, it requires no stretch of imagination to calculate the effect upon the concrete or masonry. Enough water will be taken in through a crack before the crack is filled to attack and injure the steel.

Again, many engineers believe that by increasing the steel reinforcement the cracking of concrete will be prevented and the concrete also be made watertight. The speaker has long

contended that embedding steel in concrete may or may not injure the concrete. We appreciate that this is a rather bold assertion. To elucidate this theory, and, in fact, to better understand the deeper, more scientific, more fascinating side of waterproofing engineering, we beg you will indulge him in a brief analysis of moisture.

In this connection the speaker will draw a comparison between concrete with steel embedded therein and a geological stratum. Moisture is creative and it is destructive. Of all forces it is the greatest. Nearly two thirds of the globe is water — a wise provision of nature. Moisture generates heat and, in the generic sense, there is no heat without moisture. Rust formation is an explosive force even greater than that of freezing water. Iron is one of the most important and the most abundantly distributed chemical elements in nature; purposely so, if we may so express it. Iron has a wonderful affinity for moisture, which it will draw through many feet of rock and soil and, eventually, deep down into subterranean rivers, lakes and seas, of fresh or salt, hard or mineral, cold or boiling water, which in its further course of percolating through the earth's varied strata originates chemical action, — heat, ignition, combustion, — the expanding, pent-up steam and gases finally bursting in a volcanic eruption.

The laws of nature are inexorable and always remain the same no matter in what new form they may be expressed. In the pride and glamor of our marvelous artificialities we sometimes get so far away from natural law or first principles that we must go back to locate ourselves, as it were, and start anew.

For instance, in taking sand, stone, lime, cement — all earthy matter — and forming them into a hydrated material, to which we then add iron, we are simply forming a typical geological stratum, all the elements therein (particularly the steel) having, in a greater or less degree, a strong affinity for moisture. We incorporate the steel to strengthen the cement, or the cement to protect the steel, but fail to take the next step forward and protect the cement. Adding more cement to it, in the form of cement plaster, is not adequate protection. What is the natural result? Moisture is readily absorbed by the cement, either by capillarity or through cracks, while the greater affinity of the steel alone would, and does, of itself, draw moisture through 2 ft. of cement. The moisture in passing through the cement takes up certain salts injurious to the steel. When the moisture reaches the steel, chemical action ensues,

heat is generated through decomposition or corrosion, the pent-up gas (liberated hydrogen) escaping by bursting off a brown, infinitesimal, volcanic cone, which we call rust.

And thus we have expressed, only in a different way, the same changeless natural law underlying the volcanic eruption. We are at the exact point in the circle whence we started, only, spiral-like, a little higher up. In both cases, *i. e.*, in the earth and the cement, the iron is imbedded and out of sight, and no one knows what degree of change in it has happened. We do know, by the natural law, that some change is occurring to the steel imbedded in the cement. We know that steel, imbedded in cement and kept dry, will indefinitely retain its purity and strength. We know also that moisture, reaching the steel, creates corrosion. The immediate effect is to destroy the bond between the steel and the concrete. The heat and expanding gas from decomposition (which is progressive) press the cement away from the steel. There then no longer exists, in fact, steel-reinforced concrete, but the very opposite, and a menace to life and property, which may eventually end in a collapse. If there is a particle of iron in the plaster on the ceiling and walls of this room, it will make itself apparent by a brownish, raised spot or scale as the result of moisture in the air attracted by and decomposing the iron.

It is said that no one with an imagination will commit a crime. It seems incredulous if what has been just said be true, that any one with an imagination would add to cement or concrete in the mixing, salt, iron, slag or cinders. The same may be said of unthinking engineers and architects who would waterproof by using cement-plaster compounds. Moisture percolating through cinder-concrete will form what is commonly termed lye, which will soon eat through any steel wire, rod or girder. Because of its lightness, however, but without regard to its chemical fitness, cinder concrete is extensively used for floors — the very part of a structure most apt to collapse. Waterproofing concrete floors is a rarity, on the assumption that they are sufficiently watertight. Possibly so, but it is not the quantity of water which flows over or evaporates from the floor surface, but the small quantity which, from time to time, reaches below the surface, where it remains longer than elsewhere and is unseen, that is decaying the imbedded steel.

Waterproofing arches is still widely looked upon as a wasteful expenditure, while the waterproofing of the masonry or concrete encasing the steel columns of our tall office buildings is considered the essence of refinement.

Steel-reinforced concrete is yet but an experiment. Nor do we know the life of the modern steel office structure. One thing is sure: that the security and life of its steel skeleton depend upon how far the columns supporting the structure are at their *base*, rotting from electrolysis or moisture. We do not know, because we do not see, but that they *are* decaying is true. While painting exposed steel tends to protect it, paint prevents the bonding of the steel and cement. The life of a masonry structure is indefinite. This will better explain our first statement that imbedding steel in concrete or masonry may or may not be dangerous. It is certainly safer that steel be always open to observation and minute inspection, as, for instance, on a bridge. As gangrene in the flesh or bone will kill the living organism, so will diseased, decaying steel tend to eventually destroy the cement in which it is incorporated. Evidence in this direction is abundant if we can stop long enough in our rush to accomplish things to carefully consider it.

In the proceedings of the twenty-eighth annual convention of the American Institute of Architects, 1904, in a discussion regarding steel cage construction, Mr. Geo. B. Post, the distinguished architect, said:

"I want to say one or two words more. I meant the statement in the outset in regard to steel cage construction and its durability, not to a possible construction made with the greatest possible care, but to construction as I have seen it going up in the city of New York during the last two years, where the iron columns were given a very light coat of paint, very little attempt made to protect the joints. I presume that the great mass of joints will remain for a great period perfectly sound and safe, but the several hundred bearing joints in a building put up without any great care, put up, it seems to me, with a good deal of recklessness in a great many cases, with no protection except 8 in. of ordinary brick-work, I don't believe they will stand for any serious length of time with perfect safety. I don't know if you gentlemen have had the experience with brick walls that I have. I have seen the water in a northeast storm in the city of New York go through a 4-ft. brick wall and run down on the inside of its surface as though there was nothing there — a wall 150 ft. high, exposed to a northeast gale, the water went through the 4-ft. wall at the second story and ran down on the inside, the wall being unpainted. The condition of a beam encased in cement and in a foundation is a very poor guide for what will occur in a joint on a flat, exposed wall, with only 4 to 8 in. of unpainted masonry. Every time that a storm comes, that brick work becomes soaked with water and will remain soaked for a considerable time. I should not hesitate, individually, using great care, to put up steel cage construction of any

height, but I think that it is a matter in which we should be exceedingly careful, and I do not believe that the construction of a great many buildings which I have seen go up is of a character which will stand any longer than the beams which I took from the first tier of the Times Building when I made the alterations. The ceiling was 20 ft. high; there was running machinery in it; it was dry, clean and well-kept. There was no apparent moisture, but many of the wrought-iron beams in the ceiling had, as I say, entirely lost their integrity and strength. I don't think, if they had had steel or cast-iron beams, that the result would have been the same, but unless the greatest care is taken to prevent corrosion of the metal, there will be trouble."

In further and stronger evidence there is submitted the following extract from a very recent report (dated September 11, 1906) to the Structural Association of San Francisco, by a committee appointed to make an examination of certain cases of corrosion of metal in cinder-concrete floors:

"The cinder-concrete is somewhat porous, with occasional voids, and also contains coal, from dust up to lumps 0.75 in. diameter. Rust spots occur in the concrete, and where such spots are in contact with the metal, the corrosion is severe. The rust spots are sometimes an inch across, quite soft and easily removed by the finger nail. Occasional splinters of wood occur in the concrete, which shows that the heat was not severe, as the wood is not charred. From the position of the floors it is certain that no water has reached the concrete since April 18 and that the corrosion was prior to the fire, but it appears to be more marked where floors have been exposed to rains since the fire. The corrosion is irregular in amount. In some cases the expanded metal is only slightly rusted, and in places it is entirely destroyed; several places were noticed where a small semicircular patch had been removed from the edge of a metal strip; also at times it crossed the surface of the strip in a line, which suggested that it followed a surface crack in the metal. There seemed to be a tendency to corrosion at certain points in the diamond mesh, which would indicate that the metal had been strained in the process of setting and expanding, but there is not positive proof of this.

"The extent of the corrosion is great enough to seriously endanger the safety of the floors, and it is not probable that the floors would have supported their loads more than one to three years longer."

The committee recommended that their association try to have the building laws amended so as to exclude the use of cinder-concrete in floor slabs or for fireproofing. The protection of the floor from moisture or water, however, seems never to have occurred to the committee.

We do not want to get away from the initial point in this paper, namely, that in the formation of steel-reinforced concrete we are simply transferring certain chemical elements with no change in principle, and must needs go a step further. The suggestion occurs, therefore, that we must treat the new form of the structure as we would a living thing — a thing that moves — if we expect that particular thing to be long of safe service; otherwise we revert back to the crudity of the same first principle, linking the eruption of the volcano with the formation of rust. So considered, therefore, we again inquire, Is or is not steel a menace to concrete?

We need not dig deep into chemistry or physics to substantiate the facts. We need only take the overt fact, the evidence of our eyes, based on common sense.

If moisture is the thing, as it undoubtedly is, then moisture is the thing to be counteracted. Therein lies the prevention. The real importance of waterproofing, therefore, is not simply in keeping water out of buildings, but in protecting and preserving the imbedded steel.

Another very serious factor is this: *Concrete is not an insulator and is not proof against electrolysis.* The New York *Herald* of Sunday, August 4, contained a page-illustrated article in which the above assertion was made so startlingly clear, supported by valuable tests, that it is well worth reading. If so-called "water-tight concrete," in itself or by the addition of cement plasters or similar compounds, is not proof against electrolysis, no estimate can be made upon the future damage which the use of such methods will entail.

The real theory of waterproofing is what? It is insulation. It means to separate, to get away from. Insulation and waterproofing are correlative. There can be no natural waterproofing without insulation. It is a natural law. Therefore, any other waterproofing would seem to be erroneous — how could it be otherwise?

After due consideration, therefore, and recognizing the fact that so-called "water-tight concrete" or cement plaster or washes are *not* in themselves insulators, does it not seem necessary and logical that we seek some other method of waterproofing than to rely upon water-tightness in the concrete itself; that we get away from the concrete and provide something between the concrete and moisture, and between the concrete and the earth, to so protect and *insulate* it that water will not reach the concrete, whether it cracks or not? This brings us to the consideration of the second method, viz.,

Fig. 2. A Case of Poor Waterproofing.

Fig. 3. On Flat Work.

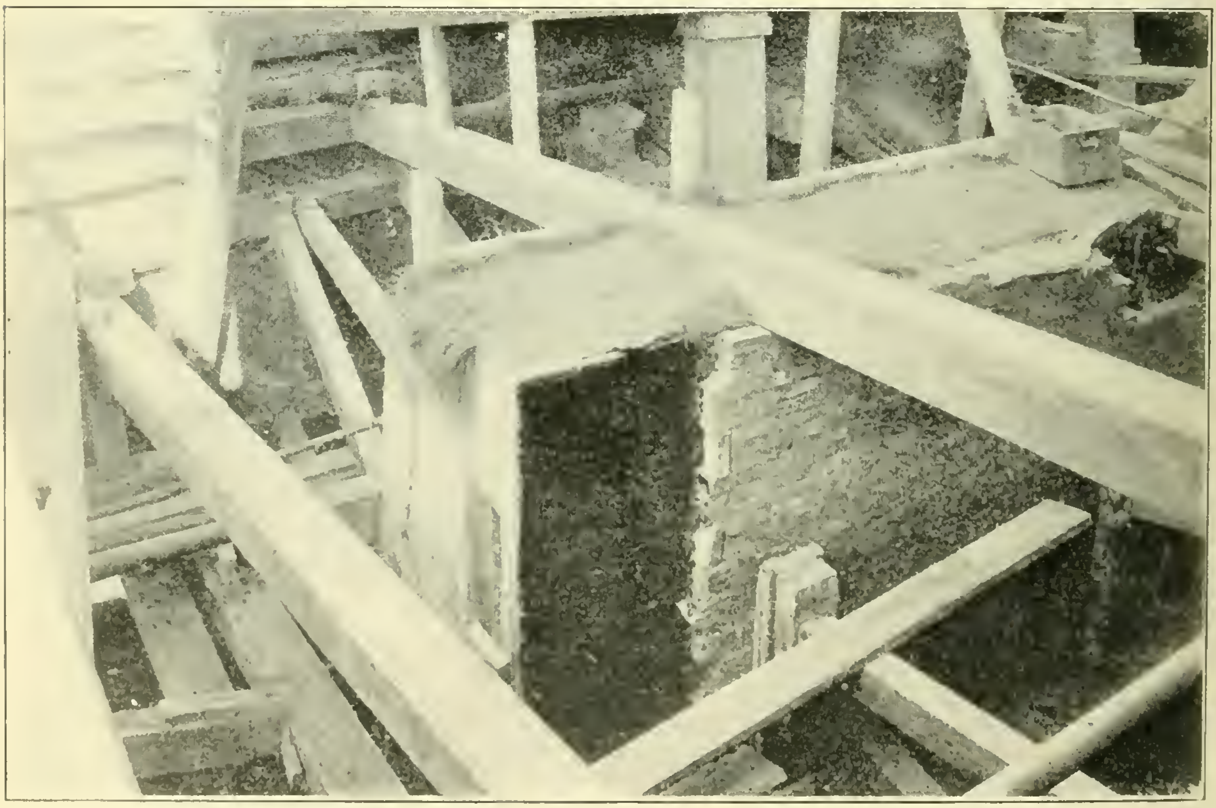


Fig. 5. On Wall Work.

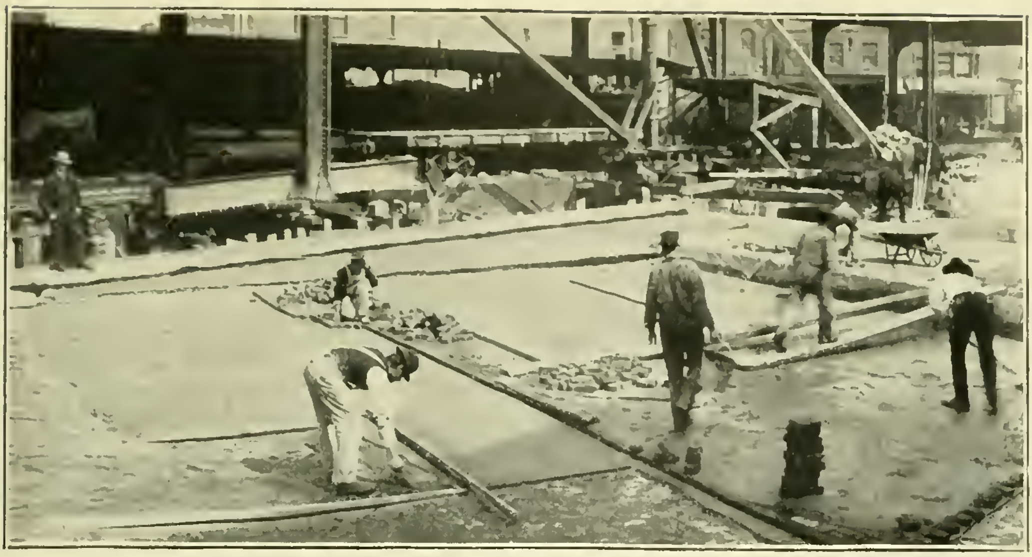


Fig. 4. On Flat Work.

Fig. 7. Preparing Surface.

Fig. 6. Rolling Felt after Mop.

Fig. 8. A Saved Viaduct.

Protecting Concrete with Something apart therefrom, to Make It Waterproof.

Under this head come those materials and methods for preventing water from coming in contact with the concrete. Practically the first efforts in this direction were to coat the surface to be waterproofed with hot coal-tar pitch or asphalt, which, however, when set and cold, cracked and separated with any settling or cracking of the masonry. Burlap was subsequently used to reinforce the pitch or asphalt, without, however, preventing them from cracking, and the burlap, being of itself not waterproof, did not give waterproofness. Later on, there came into use for this purpose tar paper, which, however, lacks pliability and tensile strength. Tar and tar paper have been extensively used for waterproofing in the past, simply because there was nothing else open to the profession. It was not until recent years that any serious effort was made to place waterproofing on a scientific basis and to make materials specially adapted to the various conditions, materials which would not become brittle or be injuriously acted upon by water, the salts in the earth, alkali in cement, etc. The result of this specialization has been to greatly improve methods, and to open to the profession products for difficult work and special conditions, considerably in advance of old-school materials.

There are also used for waterproofing, mastics composed of coal-tar pitch, or asphalt, mixed with sand or torpedo gravel, resembling somewhat, when finished, an asphalt pavement. Mastics on floors, especially on bridge floors, where there is considerable vibration, soon separate from walls, steel columns and girders. If the mastic is made soft enough so as not to crack in winter, it becomes too soft to bear the load of traffic in summer. The chief objection to mastics is that they crack clear through, with any contraction and expansion or cracking of the masonry or concrete surface, of which they become an integral part when applied hot thereon.

Specifications also frequently require that the interior surfaces of foundation walls and floors shall be given one or two coats of some waterproofing paint. The paints might be excellent materials in themselves, but their use for such a purpose is a sheer waste of time and money as they cannot possibly prevent, for a number of obvious reasons, the percolation of water through the wall, or protect the imbedded steel. There are also now on the market a number of what are termed "textile" waterproofing materials, which, on examination, will be found composed, in many instances, of simply burlap, *i. e.*, ordinary

commercial bagging. The fiber is vegetable, is extracted from the bark of trees and is very perishable, especially in underground conditions. The apparent strength of such materials misleads one into using them, whereas strength *alone* is not, by any means, the first essential in a waterproofing material. These saturated textiles or baggings are, in a measure, going backward to the old-school method of incorporating burlap with pitch or asphalt to reinforce it as steel reinforces concrete. There is a clear distinction, however, between the principle and results to be obtained in reinforcing concrete with steel, and reinforcing waterproofing with burlaped textiles. The two should not be confounded. Otherwise it would be advisable to reinforce the bitumen with copper mesh. The treated or saturated burlap is no more waterproof, especially for water-pressure work, than when originally used to hold pitch or asphalt on a wall. This can be easily tested by placing a single sheet or thickness of the treated material under the slightest water-pressure, when it will be found, within a few hours or days, that water easily passes through the interstices of the material. A woven fabric has never proved superior for waterproofing, even though it be canvas, because the fibers pull against instead of with each other, resulting in the opening of the interstices and the usual splitting of the fabric.

The best material is unquestionably a strong, fibrous felt, made in itself, *i. e.*, in one sheet, absolutely impervious to water by a process of saturation and coating with materials specially adapted to withstand the injurious action of water, and particularly all underground conditions. It is then practically an impervious membrane or skin through which, of course, in one sheet, water will not pass. As many layers thereof as the conditions require can be then cemented or veneered together with a waterproof bitumen-cement, not too weak or hard and brittle for the felt, but as strong and elastic as the felt. This forms a waterproof stratum so strong, tough and pliable that, without injury, it can be readily pulled, bent, turned, twisted, etc. Whether in a building foundation, covering the floor of a bridge or enveloping a tunnel,— it readily conforms to the final conformation of the surface waterproofed, from which it is practically *apart* and which it insulates and protects under all conditions, settlement, jars, shocks, cracks, expansion, contraction, heat, snow, ice, water, etc.

The speaker some time ago termed this " the membrane method," and firmly believes it the basis for the development of

a perfect waterproofing. It is not, therefore, primarily a question of material, but of method.

We previously advanced the theory that our structures should be treated, in the waterproofing sense, as things that live, *i. e.*, things that move. We would again, therefore, go back to locate some first principle of natural law as a guidance, because there is nothing made by man that its prototype in some form is not somewhere in nature. No man ever devised an insulation for the most intricate electrical machinery as perfect as the insulation of the human brain — the dynamo of the universe. In seeking a guide, therefore, in our present problem, we find throughout nature no waterproofing which is hard or set or vitreous, because nature waterproofs only living things (things that move), not dead ones or inorganic ones, which do not require it, but, by moisture, heat and decomposition are resolved back into carbonate of lime. Therefore, all things that live and move require, and are by necessity protected with, a flexible, elastic skin, yielding to growth, movement, action. Therein lies the origin, the first principle of waterproofing, natural or artificial. Can any other principle be right?

In the very beginning of germination, nature begins to cover, insulate and protect, with an elastic film, skin or membrane, the life germ. This law prevails through the whole line of plant and animal life, from a grain of wheat up to a mastodon. Puncture this protecting skin or membrane and there immediately ensues decomposition (or corrosion) in the exposed flesh. So long as the plant or animal lives, whether one or a hundred years, this yielding membrane perfectly protects. We ourselves take the tough hide and the fine elastic skin of animals to protect our feet and waterproof our hands, both our own and the artificial protection readily yielding to every move of the foot or hand.

If a chicken came forth in a coating of soap and alum, its usefulness would end with its appearance. Nor do we waterproof our feet or our hands by immersing them in a bath of cement, which would make them set, rigid and useless. Yet, is this not essentially what we do when we would protect and waterproof our structures, which must settle, contract, expand and *move*, with an injection of hardening fluid to embalm them, thus preventing instead of providing for the natural functions of the masonry or concrete, and also imperiling both the waterproofness and the usefulness of the structure? Obviously, therefore, a natural waterproofing is one which — skin, hide or

membranelike — yields to the natural contraction and expansion of the structure and protects it by preventing water from reaching it. If, therefore, the skin or membrane theory is logical, natural and right, it then simply remains to develop that theory and to scientifically perfect the materials necessary for its practical success.

Considered in this light, *i. e.*, following the membrane idea, and coming down to the actual work of preventing water from reaching the structure and insulating it, we would submit the following observations and rules:

Practical Application of Waterproofing.

First. No waterproofing, especially for difficult and water-pressure work, should be undertaken when the temperature is below 25 degrees fahr.

Fifty per cent. better work can be done when the weather is warm. In cold weather the felt sheets are difficult to handle, the hot bitumen-cement chills and congeals too quickly, especially when it comes in contact with a cold wall, and it is difficult to obtain the perfect cohesion of the different felt layers.

Second. Allow sufficient time, room and accommodations in which to properly apply the materials.

The reverse of this rule, however, is the common practice. No other part of construction work depends more upon the perfection of details than waterproofing. Yet there is no part of such work which receives so little appreciation and consideration. To not make every provision for facilitating waterproofing work is a great mistake. No matter how conscientious a workman may be, he cannot, for example, do good work on a wall from the outside if the excavation is not wide enough from the wall to give him room in which to work, or on the inside of the wall if he has scarcely light or arm room, and is crowded upon by workers in brick, in cement, in stone, in steel, etc.; nor on the roof of a subway, under railway tracks, if there is not sufficient head and working room between the roof of the subway and the base of the tracks, etc. This lack of consideration, in not providing time, room and the necessary facilities, and in allowing contractors to apply the materials in any haphazard way, so long as the materials are applied, is the real cause of so many past failures. Nothing pays better than good waterproofing, and nothing is more disastrous than poor waterproofing. Once water gets behind waterproofing, no waterproofing would have been preferable.

Third. Design the structure to properly receive waterproofing.

The design will either make impossible proper waterproofing, or will invalidate the best materials after they are in place. The line of waterproofing should be adapted to the nature and purpose of the structure, and be logical with the point of water-pressure.

As an example of a faulty design, there is submitted the following sketch, frequently used in trade pamphlets of waterproofing materials. It has, in fact, been adopted in the department of buildings in one of our largest cities, and shows how easy it is to officially endorse and follow a bad principle.

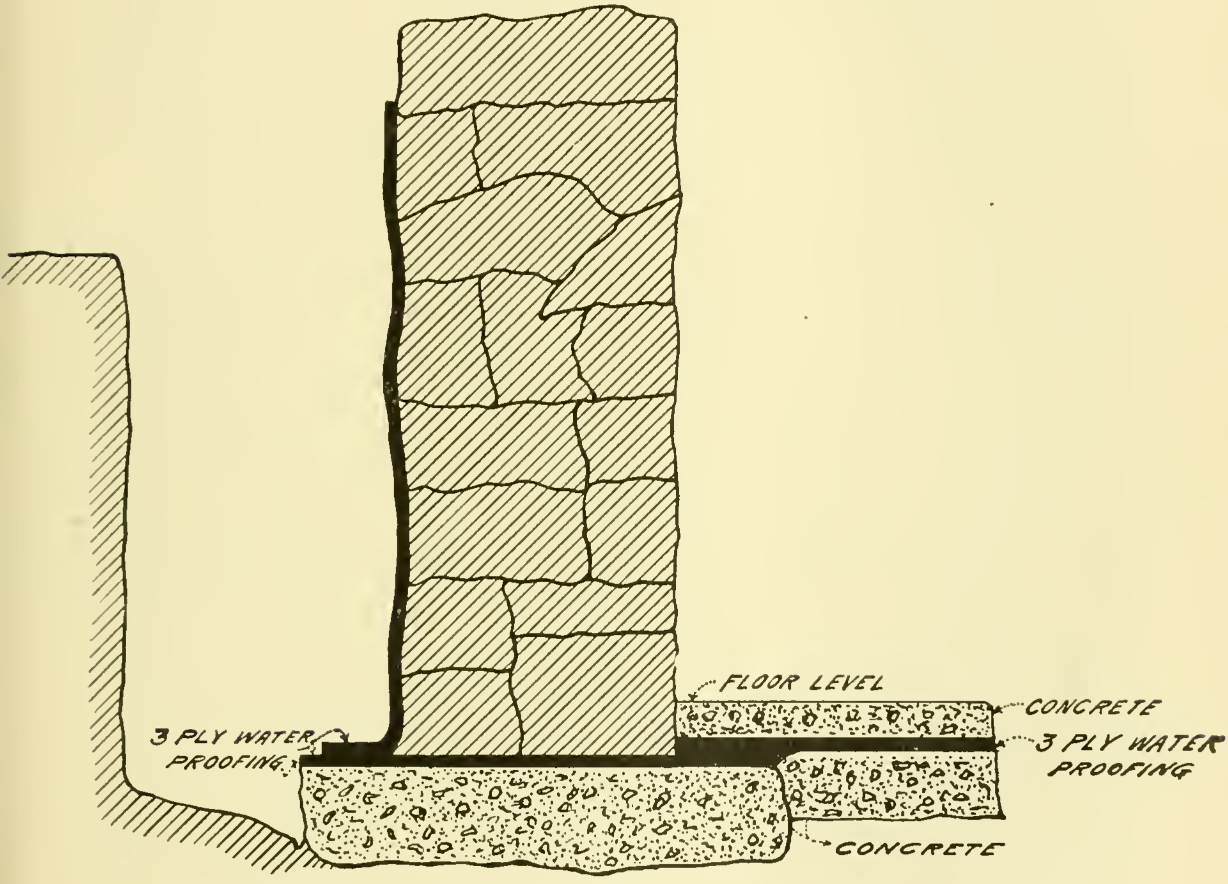


FIG. 1. A WRONG DESIGN.

Fourth. Specify always that the waterproofing shall be done only by experienced and skilled labor.

Roofing, for instance, is not waterproofing. An excellent example of this is shown in Fig. 2, in which "waterproofing," is applied to the back of a retaining wall. The contractor, a roofer, was so proud of his work that he had the picture taken to illustrate it. It requires no trained eye to see that the surface of the retaining wall is, in the first place, too rough, and is not

rightly smoothed, to waterproof; that the corners of the wall and the edges of the steps are round and badly broken instead of being neat and square, making it almost impossible to fit the layers of felt around same. The waterproofing itself is slovenly and irregularly applied, underlaid with air pockets, not properly lapped or smooth and tight. No skilled waterproofer would, at the outset, have applied the materials to such a surface. He would have refrained from doing so until the surface was properly prepared. This is also a case where possibly the engineer did not himself know—but engineers cannot be expected to know all things.

Fifth. Thoroughly protect the waterproofing during and after application.

The average laborer is no respecter of waterproofing, especially an elastic waterproofing, and will walk on it, roll wheelbarrows over it, throw tools, lumber, brick, stones, cement and débris thereon, to its serious damage.

After arches are waterproofed it is a common mistake in placing the fill to not begin the fill at the base of the arch, but to dump it on the crown. The fill thus often breaks through and tears or strips the waterproofing from the arch surface. It is false economy to not always permanently protect waterproofing with a layer of brick or cement mortar. Examples of such a protection are shown in the accompanying figures:

Fig. 3 shows bridge floor waterproofing protected with hard brick, laid flat and fairly close in a thick coating of the hot bitumen cement, the joints being filled with the cement, with which the bricks are also finally coated. Over the brick is placed sand or stone ballast, in which rest the ties for the rails.

Fig. 4 shows another method of protecting the waterproofing. The man in the middle foreground is placing cement mortar directly over the waterproofing; while the man beyond him is laying brick on top of the cement mortar. Immediately to the right of the brick layer is seen another course of cement mortar which has been placed over the brick.

Fig. 5 shows the protection of wall waterproofing by a 4-in. course of brick laid against the wall in cement mortar.

Fig. 6 is an example of the best method of applying the felt, especially on flat surfaces. It shows the felt being rolled after the mop which spreads on the hot cement. Rolling presses out air bubbles and insures better sticking. A workman follows, rubbing and pressing the felt over the entire surface to insure thorough adhesion to the under layer. Just letting the felt fall

flat into the hot bitumen cement is *not* rolling it into the hot bitumen cement.

Fig. 7 shows a bird's-eye view of the series of arches, on one of which the waterproofing was shown to be in process in the previous picture, No. 6. The man in the middle foreground is trowel-smoothing the concrete surface for the waterproofing.

This concrete viaduct (Fig. 8), with its graceful arches, was erected in 1902 without being waterproofed. The result was that within the short space of three years the condition of the viaduct was such that, in order to save it, it was necessary to remove a greater portion of the top surface and place thereon waterproofing which should have been applied in the first instance. This condition was brought about by the weep pipes at the bottom of the reservoirs between the arches filling up from cementation, permitting the reservoirs to fill with water which percolated in streams through the concrete. The water in the reservoirs, and that which saturated the body of the concrete in the arches, froze in the winter, causing the arches to spread and split, thus endangering the entire structure. Even at the present day a great many engineers and architects look upon the waterproofing of viaducts and arches as unnecessary. In contradiction, can any evidence stronger than the above be cited? A membrane or stratum of waterproofing over the arch under the wearing surface not only prevents the unsightly discoloration of the arch, but preserves both its beauty and integrity.

Sixth. Inspect waterproofing at all times during application.

See that the materials as specified are used, and also that they are themselves up to standard; that the work is done carefully and skillfully, particularly in the out-of-the-way small difficult places; that the laps are not made 22 in. when they should be 24 in.; that the hot cementing material is applied, not one fourth or one half, but the entire width of the lap; and that it is applied *hot*, quickly and thoroughly; that full, clean and well-protected connections are provided; that the waterproofing is well protected at the end of the day's work; that no work is done except in the presence, and by the approval of, the special inspector appointed over the work.

If the inspector is himself not thoroughly skilled in waterproofing he is of no value. He might be an expert in steel or cement or caisson work, but without the right experience in, and the knowledge of, waterproofing, the waterproofing men under him could easily deceive him in important details of the

very thing which is to make permanently safe and valuable the steel and cement. If the waterproofing is very important. expert direction and supervision should be obtained.

Seventh. Do not depend on guarantees.

The speaker has always contended that a waterproofing guarantee is practically worthless. A roofing guarantee is of value because the conditions are entirely different. In roofing, the cause of and responsibility for leaks can be easily settled. Seldom, however, is there any recovery had under a waterproofing guarantee. Bonding companies are averse to supporting waterproofing guarantees because of the high risk. It will be found on close analysis that bonded guarantees do not, in fact, guarantee. Such, for example, is a bonded guarantee reading that the structure or surface to which the waterproofing is applied must remain " sound and stable."

The very purpose of waterproofing is to waterproof the structure or surface in the event of its *not* remaining " sound and stable." Such a guarantee, of course, means nothing, except that the bonding or other company assumes no risk, but shifts it to the owner of the structure, who himself then guarantees that his structure or wall will not crack or injure the waterproofing. The waterproofing should accommodate itself to the wall instead of the wall accommodating itself to the waterproofing. The best guarantee is work, intelligently, skillfully and honestly executed by a concern of reliability and reputation.

A strong case in point is a recent decision on a waterproofing guarantee by the United States Circuit Court of Appeals, Third Circuit, 144 Federal Report, 942. In a contract for the foundation of a building the specifications, after describing the waterproofing materials to be used, stated: " The whole to be made perfectly water-tight and guaranteed." On the completion of the foundation it leaked and payment was withheld from the contractor. The contractor contended that he had strictly followed the specifications and was not accountable for the result of the plans. The court upheld the claim of the contractor.

Eighth. Do not use a set or standard specification.

Each design must suit the exact conditions, and each specification must exactly suit the design. Using a set or standard specification frequently offsets the very purpose desired. It results in the customary but very serious mistake of placing the waterproofing details on the contractor. A contractor will

apply anything that is specified, and, as a rule, is interested only in getting it applied as quickly as possible. Speed in waterproofing is undesirable and dangerous. The specification as to waterproofing, particularly in important work, should be clear and to the point in every detail. It should make the contractor responsible only for the proper application of the materials under the close observation and approval of the engineer.

In the final analysis, the sanitariness, soundness, safety, preservation, usefulness, symmetry and beauty of any structure depend upon protecting it against the destructive action of moisture.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1908, for publication in a subsequent number of the JOURNAL.]

THE APPRAISAL AND DEPRECIATION OF WATER WORKS AND SIMILAR PROPERTIES.

By William H. Bryan, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 6, 1907.]

This subject involves many intricate questions, and although it has been much discussed in recent years, it will, in the author's judgment, repay further study.

It may perhaps be of interest to add that at the time of preparing this paper the author had in hand the appraisal of a water system, and occupied the unusual position of having been selected by both parties in interest, the city and the company. He was particularly anxious, therefore, to have before him a clear, concise and just statement of all the considerations which might fairly affect the case from every possible standpoint.

Changes of ownership often occur in industrial or public utility plants. Frequently a water-works system or an electric-light plant is taken over by the municipality in which it is located. Private plants often pass from one ownership to another. Both public and private plants not infrequently desire to raise money by issuing bonds upon their properties. Sometimes, as in Illinois and California, the rates for service are based on the investment in plant; not infrequently such appraisals are desired as a basis of taxation. When questions of this character arise it becomes necessary to ascertain the value of the installation. As such appraisals are usually made by engineers, it is important that we have a clear understanding of the considerations involved.

The form of procedure is usually determined by the franchise or other agreement existing between the city and the company. Such franchises are usually granted for specific periods, — in Missouri for twenty years. The city often reserves the right to purchase at the end of five, ten or fifteen years, and almost invariably at the end of the franchise period. Usually the city must give ample notice in advance of its intention to purchase. The appraisal is generally made by a board of three, one selected by the city, one by the company, these two selecting the third. If they cannot agree, it is often provided that some court of

local jurisdiction, or the governor of the state, shall appoint the third member. It is sometimes stipulated that should the company fail or refuse to appoint its representative, then the court shall appoint a suitable person who shall act on behalf of the company. These appraisers are usually required to be experienced and disinterested parties; often they must be non-residents. The finding of the majority of the board is usually conclusive, and the city has the right to purchase at the price fixed. Failure to exercise this right acts as a waiver until the next purchase date. If there has been no purchase at the end of the franchise period, the usual provision is that the franchise must be renewed. In some cases there must be a revision of public and private rates at that time. In some franchises there is no provision as to the relations which are to exist after the expiration of the franchise in the event that the city does not purchase. In no case which has come under the author's observation has it been compulsory for the city to purchase at the price fixed, although the company was obliged to sell if the city chose to buy. If the city does not exercise its option, then the franchise and contract continue, except when the original franchise period has expired, when serious complications often arise.

In some cases it has been claimed that the city council has no power to bind the people for longer than a fixed period, — usually twenty to thirty years,— even when such action has been confirmed by vote. This may mean that the provisions intended to cover the situation at the expiration of the franchise period — those governing the sale of plant, or renewal of franchise — are non-enforceable. When one or the other of the parties thinks it for his interest to take this position, the situation is indeed "up in the air." As a rule, however, the courts have refused to sanction anything which savors of confiscation or of compulsion, and they will not usually allow the installation of a competing system. In the end, the city usually takes the existing plant, but is not required to pay a fancy or "boosted" price for it.

The wording of the franchise is often indefinite as to what value is meant and how it shall be arrived at. Common expressions are "the value," "the cash value," "the then cash value," "the appraised value," "the fair valuation" and "the fair and equitable valuation." Some special cases which have come under the author's observation are: "All values of the property"; "the fair valuation of said works, and all property connected therewith"; "the fair value plus such actual damage

as the company sustained by reason of the sale" ; "fair valuation, to include works, privileges, property and the productive value"; "the fair and equitable value, *i. e.*, the actual value of works, lands, buildings, machinery and equipment, including franchise"; which latter, I confess, was a "stunner." In one case 10 per cent. was to be added to value of the plant as found by the appraisers. A well-known case in Maine was conducted under the right of eminent domain. The appraisers were to be appointed by the court and were to fix the "fair, equitable and just value of plant, property, franchises, rights and privileges." In this case either party was authorized to apply to the Supreme Court for instructions, and this being done, the court laid down an exhaustive and well-digested set of rules governing all aspects of the case, which to this day form valuable precedents. In many cases it is stipulated that no allowance is to be made for the "franchise" value, and when this is the case it greatly simplifies the situation.

What is meant by the "value" of a plant, that is, the physical features, in this connection? Undoubtedly we mean such an amount as will fairly measure its ability, at the time of appraisal, to perform the work for which it was installed. This, of course, bars from consideration its second-hand, forced sale or scrap value. It has also been expressed as "the value to a seller who is willing, but not compelled, to sell, and the value to a buyer who is willing, but not compelled, to buy." As in any other trade, both sides must be satisfied. Practically the same conditions should govern as if one private individual or corporation sold to another.

Above all, the value must be a fair one. There should be no "hold-up" methods employed by either party, as is unfortunately too often the case. However plausible the arguments on either side may appear, they are valueless in a fair appraisal if they do not recognize that they must appeal to the other party as just and equitable. The company should not place inflated values on an antiquated or inefficient plant, or upon present or prospective earnings, often unduly padded, or upon the fact that it is in possession of the field. On the other hand, the city should not take undue advantage of the fact that it can compel the sale of the plant and that it controls the rates for service, and even the franchise grant itself. Should either side take what appears to be an unreasonable position, the other party would be justified in protecting itself by all legitimate means at its command.

Is it possible for such a value to be fair and reasonable to one party and not to the other? The author believes not. The company may feel that it deserves a greater award, but if the figure named is the maximum which the city is warranted in paying as a sound business proposition, then no higher award is justifiable. On the other hand, the city may feel that it has not received tangible value, or that some features are over-estimated. But if the amount represents definite values, whether "physical," "going" or "franchise," on which the city is in a position to conduct a self-supporting enterprise, then it is fair also to the city. The fair value is inherent in the system itself, and is independent of ownership.

To this, one exception may be noted. Sometimes the law requires the city to set aside a sinking fund of sufficient amount to liquidate the bonds issued to pay for the plant, in a definite period, which period may be less than the life of the plant. A private company need only set aside such a fund as will exactly offset depreciation. In such cases the city's sinking fund and the corresponding annual operating expense must be larger than in the case of a private company. In a recent case which came under the author's observation the actual depreciation was only 1.5 per cent. per year, while to repay the bonds in the required period of twenty years would have called for an annual sinking fund of 3.72 per cent., the rate of compound interest being 3 per cent. in both cases. In such a case the fair value of the plant to the city would be less than the fair value to the company, other considerations being identical. This, however, would just about offset the lower rate at which the city can borrow money.

It is possible that the value of a plant at the time of appraisal may actually be greater than its original cost:

1. There may have been a material advance in the cost of such construction, so that it would cost more to reproduce it.

2. It may be earning legitimate profits at reasonable rates, with the right to continue such earnings.

3. It may have demonstrated its exact and entire suitability to the work for which it was intended, in capacity, strength, power, efficiency and reliability. All doubtful and uncertain questions have been solved. Under such conditions it is certainly worth more than can be measured by the mere cost of a new and untried system.

On the other hand, its value may decrease in many ways:

1. By normal depreciation, wear and tear, or decay of parts, so that they are in need of reconstruction or renewal.

2. By reduced cost of reproduction.

3. By poor design, resulting in demonstrated unsuitability for the work.

(*a.*) The pumping engines, for instance, may be too large or too small. They may not be powerful enough, or there may not be sufficient strength to safely work against the necessary pressures.

(*b.*) Inefficiencies may have developed, resulting in large fuel costs, repairs and maintenance expense, or leakages. The units may not be of suitable modern design.

(*c.*) Excessive wear and tear may have occurred, indicating short life.

(*d.*) There may have developed a lack of reliability, the units being subject to interruptions of service, breakdowns, etc.

4. While the plant may have originally been well adapted to its work, it may become more and more unsuitable as years pass, owing to increased demand or other changed conditions.

5. The plant may deteriorate in value, although of excellent design and construction, as a result of external conditions, which may limit the patronage and reduce the net income.

(*a.*) In water works the supply may be poor in quality, or insufficient in quantity, or both. It may become more and more polluted, or the river may leave the pumping station, as the Missouri river has a way of doing.

(*b.*) The company may be unpopular, due to poor management in either the business or mechanical departments, or for other reasons.

(*c.*) There may be uncertainty as to the future. The franchise and city contracts may expire, and there may be a possibility of rates being lowered.

(*d.*) The existing rates may not be those best adapted to secure the highest net revenue. They may be either too high or too low.

Such valuations may be made in many different ways, those most customary being:

1. Value based upon the original cost of the plant as it exists at the time of appraisal, omitting worn-out or replaced material. To the actual cost of material and labor there should always be added a reasonable sum for necessary general expense, such as administration, legal matters, engineering, superintendence, tests, insurance, use of plant and tools and interest on the money invested up to the beginning of service. Sometimes it is proper to include a contractor's profit. It should be re-

membered that the plant was not built all at once, but piecemeal. Allowance should be made for whatever effect this may have had upon cost.

2. Original cost as above, and in addition the cost of all discarded or changed units. Such a valuation has been advocated on the ground that the sellers are entitled to be reimbursed for all moneys they have put into the enterprise, the claim being that such expenditures for replacement and renewal are necessary and incident to the business.

3. Original cost based on either of the above plans, and, in addition, interest on the investment until the plant becomes self-sustaining. In some cases it has even been argued that interest should be included over the entire period up to the date of appraisal. Water plants are always built more for future than for present needs, and the cost of carrying them until needed may be a reasonable element of value.

4. Original cost computed by either of the above methods, and, in addition, such unavoidable losses as were sustained in the legitimate operation and maintenance of the plant during its earlier years. Private parties do not hesitate to conduct an enterprise at a loss for a few years, when it seems reasonably certain that they will, in the end, have built up a profitable business. Such losses are usually charged up as one item of the cost of establishing the business and become a part of the invested capital. It may be argued that had not the owners bravely footed the losses in the earlier years the plant would never have persisted so as to have reached a profitable condition. Furthermore, had the purchasers themselves undertaken the business at the time the owners did, they would have had to go through a similar unprofitable period. It would seem unfair to take over the plant just when it has reached a satisfactory financial condition without reimbursement for the earlier losses, particularly when the legitimate profit is growing and would soon have wiped out these losses. This, as shown later, approaches the "going" value.

5. From the original cost, determined in any of the above ways, deduct the depreciation the plant has suffered up to the date of appraisal. This method is an attempt to arrive at the actual physical value of the plant.

6. Original cost less depreciation, plus what is known as the "going" value. This latter is of comparatively recent development, but, having much to commend it, now has the sanction of many high authorities. It is the value such a plant

has, over and above its physical value, due to the fact that it is not a bare and idle system, but it is in actual operation, doing business with large numbers of connected customers. It is something like the " good will " of a business, but is even more tangible, as the customers have expended money preparing to use the service and are not likely to discontinue it. Water is a necessity, and in many cases a satisfactory supply cannot be had except from the company. Time, money and intelligent effort have been spent in educating the people up to an apprecia-tion of the many benefits of the use of water under pressure,— its convenience, saving of labor and healthfulness. In many cases solicitors have been employed, connections made free and water supplied without charge for limited periods, all of which expense is believed to be justified by the prospective income. This may continue legitimately long after the system is on a self-supporting basis. Such a plant is unquestionably worth more than a plant of equal physical value, but without connec-tions or business, which it would have to build up by the usual slow process. The " going " value is independent of the fran-chise value, and may exist where the franchise has expired. It is extremely difficult to place a definite figure upon this value. Some writers have suggested elaborate methods, to which they have evidently given much study, but they involve so many assumptions on which equally able appraisers might honestly differ as to be of doubtful value. It seems to the author that a simpler and less speculative method which has been proposed answers the purpose much better. What did it actually cost the original owner to bring the plant to a self-supporting basis? Is not this represented by the losses of the earlier years of opera-tion? This appears to be an additional argument for method No. 4. It must not be forgotten, however, that the courts have refused to allow anything for " good will " considered on its own basis, where the business is exclusive.

In any valuation which excludes consideration of net earnings it would seem that the appraiser is limited to the cost or value of the plant itself as it stands at the time of proposed transfer. " Going " value, should, therefore, only be considered in so far as it has affected the total cost. Whatever time or money the owners have spent legitimately in building up the business, or in early losses, may, in the author's judgment, fairly be allowed them as " going " value. But where the in-crease has resulted more from the natural growth of the com-munity than from any efforts or expenditure on the company's

part, the allowance should be small. This is particularly applicable where the appraisal is to serve as a basis for rate making.

7. The estimated cost of reproducing the plant at the date of appraisal. This is manifestly the fairest method, as it bases the transaction upon existing conditions, and it is now the one most generally followed. There is a distinction between cost and value, and the latter is what we are usually after. It is often impossible to ascertain the original cost, but it is not unusually difficult to get at the market prices on material and labor at the time of the appraisal. This rule, however, is subject to exceptions, as when such costs are temporarily abnormal, as, for instance, when prices happen to be soaring, or unduly depressed, or where, for example, the patterns of a particular pumping engine may have been destroyed, and the cost of replacing them would come in.

8. The cost of reproduction, less depreciation, as before.

9. The cost of reproduction, less depreciation, plus "going" value.

10. The "franchise" value, based upon the earning power of the system. This, of course, presupposes that there is a legal franchise, and that it has a considerable period still to run, and that its wording permits the consideration of this feature. In such cases there must be no trouble as to rates, no prospect that they may be reduced. The plant must be adequate to maintain the service. If not, there should be deducted a sum sufficient to bring the plant up to good working condition. There must be no trouble with the water supply, either as to quality or quantity. Such values are usually reached by computing the present value of future net earnings during the unexpired portion of the franchise. Great care must be taken to place the gross income on a conservative basis, keeping in mind the possibility of rate reductions. The operating expenses must be looked into with equal care. They must include not only the ordinary items of labor, fuel, oil, repairs, and maintenance but also administration and office expense, taxes, insurance, interest on the investment, and an annual and uniform charge to sinking fund sufficient in amount to renew all wearing parts as it becomes necessary.

As to the propriety of placing a value on earning power, it would seem sufficient to say that when a company is in the enjoyment of a profitable business, it is reasonable to suppose that a fair amount of brains and good business management have

been put into the enterprise, to all of which the city succeeds. Certainly if the opposite is the case, if there are no profits, but, on the contrary, continued deficits, no purchaser would pay even the physical value of the plant. A city has undoubtedly the right to grant a franchise for a public service for a limited period, and then to take back to itself that service. If that intention is clearly stated in the franchise it would seem that as the owners have had all that their contract entitled them to, they should receive merely the physical value of the plant, plus its "going" value. On the other hand, it would seem equally clear that the ability of a plant to earn legitimate profits is a proper element of its value when its consideration is not expressly prohibited.

11. Scrap or salvage value. This is rarely used, as it seldom happens that a plant goes completely out of business. Occasionally radical alterations are necessary, due to change in the source of supply, location of reservoir or pump house, or to growth of the city in an unexpected direction. Single units, such as boilers, pumping engines or filters, often wear out and are abandoned, but rarely or never an entire plant.

Such valuations are often complicated by the conditions laid down in the franchise to govern the work. Where these directions are clear they should be followed to the letter. Often, however, they have been loosely drawn and have resulted in endless litigation. Even where the meaning is reasonably clear to the layman, skilled lawyers, retained by the one side or the other, have succeeded in casting more or less ambiguity upon it.

Evidently there is wide choice as to which of these methods shall be used in any given case. If the principals in interest can agree as to the method of valuation, they should give explicit instructions accordingly. This will save a vast amount of trouble. If, as more often happens, no such instructions are to be had, then the engineer must use his best judgment and select that method which appeals to him as being the fairest. The considerations governing his selection of method should be sound and he should approach the matter without bias. His reasoning should be such as will be admitted to be fair by both parties. Particularly should this be the case where he is the arbitrator, or a member of a board of arbitration. He should never forget the judicial position he occupies. If, however, he is retained by either party to the controversy to appear as an expert before such a board, or in court, then it is his duty to see

that all the evidence, data and argument which legitimately and properly affect his client's case are fully and clearly presented. In those cases where there is room for honest difference of opinion,— and there are many such,— he is justified, in all fairness and good faith, in seeing that the point of view which most favorably affects his client's interests is properly and clearly set forth.

A brief consideration of the eleven methods above mentioned may assist in making a proper selection.

Evidently the first four are based upon the idea of returning to the company the entire amount of money it has invested, irrespective of whether the value is still there, and without regard to whether the money was wisely expended. No consideration is given to the present condition of the plant, its efficiency, or whether it is self-suppoıting or not. Such cases are rare and would never seem to be proper except where the "going" value justified a material addition to the physical value, or where the franchise permitted consideration of value based on earnings.

Method 5 is justifiable as representing an effort to reach existing values. The proper computation of "depreciation" is, however, a matter of some difficulty, as will be seen later.

Method 6 is a still nearer approach, as are also 7, 8 and 9. The latter represents the author's ideas more fully than any of the others.

In those cases, however, where it is proper to consider franchise or earning value, then Method 10 should be given due study in connection with the physical and "going" values, as already explained.

Plan 11 is of such rare application as to need no further consideration.

Methods 9 and 10 appearing to be the pıeferable ones, they will be considered in further detail.

Clearly the two are interdependent. The plant may be of excellent design and in first-class condition, but if operated at a financial loss its value is correspondingly reduced. On the other hand, the net earnings may justify a value above that of the physical property alone. The determination of the cost of reproduction usually presents no serious difficulties after a complete inventory has been prepared and verified. It then remains to assume a life period, or term of amortization, for each unit of the plant, and to compute the depreciation to date.

As will be seen later, there is some uncertainty as to the

average useful life of various portions of the plant. The inspection which accompanies the making or checking of the inventory, however, will usually throw light on this question. If any unit shows signs of decrepitude, or is of limited usefulness for any reason, it has already depreciated largely. This, with a study of the views of experienced authorities, will generally provide a basis for sound action in the premises. Some data on the life and depreciation of various features of water and other plants have been collected by the author from various sources and are tabulated later herein.

Depreciation should, of course, be figured sufficiently high to cover not only the wear and tear, lowered usefulness and obsoleteness of design, but also the possibility of accidents and of lower market prices for apparatus, material and labor at a later date of appraisal.

Two methods of determining depreciation are in common use. Under the first, known as the straight line method, after the unit under consideration has been examined and its probable life, or term of amortization, fixed, it is assumed that its value decreases uniformly during that period. If, for instance, the assumed life is twenty years, and ten have elapsed, then its value is 50 per cent. of its first cost, or the cost of reproducing it at the time of appraisal. This is the simplest, most direct and most natural method, and is the one which at first glance appeals to most engineers. The author — in common, he believes, with many others — has employed it almost exclusively heretofore. It takes no account of sinking fund or other bookkeeping methods.

A second method, and one which now has the sanction of many authorities, assumes that a fixed amount has been set aside each year at compound interest, and that this sum, and the accrued interest, form a sinking fund which, at the end of the assumed life of the unit, will be sufficient in amount for its renewal. The value at any intermediate date is the first cost, or cost of reproduction, less the gross amount of the sinking fund at that date. In the event of sale it is assumed that the new owner will continue the plan; in which event it will "pay out" for him exactly as it would have done for the original owner.

The essential difference between these two plans is that under the first the drop in value is the same every year, while under the second it is light at first, gradually increasing until towards the end, when it rises more rapidly. The loss to the original owner under Plan 2 is small, the later purchaser having

to bear the increasing depreciation losses. To what extent is this plan justified by the facts? The difference between the two methods is not great for units of short life, but it is quite marked on those portions of long duration, such as the underground mains.

Both plans, however, assume that the loss in value follows a uniform law, the first dropping by equal steps each year, and the second by gradually increasing amounts. Both assumptions are in most cases at variance with the truth. Let us consider in somewhat further detail a few of the items which enter into an ordinary water-works valuation:

Real Estate. — This is not usually subject to great fluctuations. In the smaller conservative towns values remain nearly constant. If in a progressive community, they tend to increase. In the larger growing cities there would usually be a reasonably sure and steady advance. This, of course, leaves out of consideration real estate booms, collapses, etc., which, when they occur, must be given whatever value the situation warrants.

Buildings. — The ordinary well-built structure has a long life, and its deterioration is slow and reasonably constant unless affected by external circumstances. Power plant buildings deteriorate to some extent, however, from the effects of heat, steam and moisture from boilers and pipe work, and the vibrations of machinery. More often, however, their usefulness is impaired, and often ended, by the demand for greater capacity of machinery, or newer types, which require buildings larger in size and different in character and arrangement. In addition to examining into its physical condition, therefore, it is necessary to estimate the probable future usefulness of the building and its adaptability for such future changes as may be necessary. The life of good brick buildings is variously placed at from twenty-five to one hundred years, averaging forty to fifty; ordinary frame buildings, twenty years.

Boilers. — These being subject to severe usage are probably the shortest lived portion of any plant, depending upon the service, water, fuel and care they receive. The output of the average boiler plant, however, is fairly uniform, and its loss of value equally so. After a boiler has become too worn for regular service it still has a small value for occasional use as a reserve unit, or for helping out for short periods at the peak of the load in electric plants, or at times of fire service in water works. Authorities have placed their life at from ten to twenty-five years. Mr. J. W. Alvord * collected reliable data from thirty-

* Proceedings American Water Works Association, 1903.

two boilers whose useful life ranged from six to twenty-three years, averaging fifteen.

Pumping Engines. — These have a value subject to many fluctuations. An engine which has proven itself well adapted for the intended work in capacity, power, strength, fuel, efficiency, smallness of repairs, reliability, etc., may actually be said to have increased in value when these characteristics have been fully demonstrated. It has evidently been wisely chosen, and when the attendants have fully familiarized themselves with all its characteristics, there is no longer anything experimental or uncertain about it. Assuming ordinary renewals and repairs as needed, its value for the work in hand may not drop materially for many years, as the wearing parts are easily renewed and at small expense. This condition continues until the time arrives when it is no longer large enough for the work, and an additional or larger engine must be installed. It may continue to run, however, at a lower value, doing part of the work, for some years to come, when still further additions may have to be made to the plant. These additions will probably be larger in capacity, and of higher efficiency, making it less and less desirable to run the original unit. A time will come, therefore, when it no longer pays to run this engine in regular service. After this it still has some value as a reserve unit and for helping out at times of maximum or fire service. To every engine, of course, there comes a time when it no longer pays to repair it, as, for instance, when the steam cylinders can no longer be bored out, valve seats trued up, or when the room it occupies is needed for other purposes. There is also the possibility, remote, of course, with the best types, of accident, which may seriously damage the engine, possibly beyond repair. Both engines and boilers sometimes have a considerable scrap value when no longer fit for use. Their life has been placed by good authorities at from ten to thirty-three years. Mr. Alvord's records of fifty engines ran from three to thirty-six years, averaging 21.3.

Cast-Iron Pipe. — There is wide variation among good authorities as to the average life of well-coated cast-iron pipe. Some assume it at one hundred years under favorable conditions, but there is little definite ground for such a figure. Instances are known where pipes of this age have been examined and found in good condition. In many cases, however, it has been found to be more brittle than when installed. Some waters cause a tendency to corrosion internally, and most waters make a deposit of tubercles which, even if they do not eat through the

coating, in time materially cut down the pipe's capacity. This is more noticeable with soft or surface waters than with hard waters. Furthermore, there are many soils, and many waters in the soils, which cause external decay. There is also the possibility that the demand for water for ordinary and fire service in some sections of the city may increase beyond the capacity of the existing mains. In most cases, however, it is not necessary to abandon or even change the pipe on a particular street on this account. A new line of larger capacity may be laid on the same or on a parallel street, thus bringing up the pressure throughout the entire district. This line, in connection with the existing lines, gives the improved service without abandoning the old lines, these continuing in use, doing their share of the work. In some cases considerations of first cost have compelled the installation of small mains, 3 or 4 in.; also of even smaller wrought-iron lines. These are of low capacity, subject to rapid choking up, and are practically valueless for fire protection, while the wrought-iron lines are usually short lived. For these reasons they must usually be replaced at an early date, and some authorities refuse to allow any value for them. This, however, is an extreme view. Each case should be studied on its merits, and whatever value actually remains in such lines should be awarded. In most cases depreciation results from internal incrustations cutting down the capacity of the mains, particularly for fire service. This would seem to indicate the necessity of frequent severe flushings or cleaning by scrapers or other mechanical means wherever possible. It is evidently of great importance that in every case the pipe be carefully inspected, both externally and internally. The maximum life, in good soil and with waters which form no internal incrustations, if such exist, may be said to be unknown. Knowing the effect of soils and waters, of increasing brittleness, and of higher pressures and shock, limits have been placed all the way from twenty to one hundred years, with perhaps the best practice at about seventy-five for average favorable conditions. This figure, of course, should be decreased or increased should local examination necessitate. As both the internal deposits and the demand for water are small during the earlier years, the depreciation in value is low, but it increases in the later years with growing incrustation, demand and brittleness.

Standpipes. — These may be said to increase somewhat in value at the start if they prove well adapted to their work. Their principal value in the smaller systems is for storage to

avoid night pumping. They also permit shutting down the pumps temporarily at any time, and provide an emergency supply over and above what the pumps can furnish, when needed. A further important function is the regulating of the fluctuations of demand without shock on either the pumps or the distribution system. Evidently standpipes are subject to deterioration under the ordinary effects of corrosion, ice and wear and tear generally, and their value is dependent upon the sufficiency of their dimensions and design for meeting the desired conditions satisfactorily for a term of years. There is, of course, a drop in their value when the consumption reaches such a point as to demand night pumping. Examinations of a number of standpipes by the author show greater depreciation internally than externally, assuming the outside to have been kept well painted. The bottom, which is usually found covered with sediment, is generally well preserved. Above this the same tubercles are found as in the cast-iron mains, with the important difference that under each there is a large pit where the wrought metal has been eaten away. Large numbers of rivet heads are corroded away on the upper portions of their heads, where more or less sediment has collected. These defects decrease as the height increases, ending at about the low-water line. Here there is a marked deterioration of rivet heads, but above this point the tank is usually found in good condition. Authorities place the life of ordinary wrought-iron standpipes at from twenty-five to forty years.

Reservoirs and Dams. — Assuming these to be well designed and well built, their life may be considered indefinite. Those reservoirs, however, built for the smaller cities, with earth dams and walls, intended for impounding purposes, may lose value by the effect of wave wash and sedimentation, the burrowing of animals, as well as gradually becoming too small for settling and storage. The effects of ice and freezing are also detrimental even to masonry, as are also the ordinary wear and tear of filling, emptying and cleaning, removal of sediment and the alternate exposure to air and water.

Having thus briefly outlined the progress of depreciation as it actually occurs, it remains to be seen which, if either, of the above rules offers the better method of computing present value.

Let us consider two divisions of the plant, the pumping engines and the cast-iron mains. These, in the author's judgment, fairly represent the range of the characteristic depreciations

which occur throughout a water plant. It would seem that a rule which will apply to these may safely be used with reference to the entire plant.

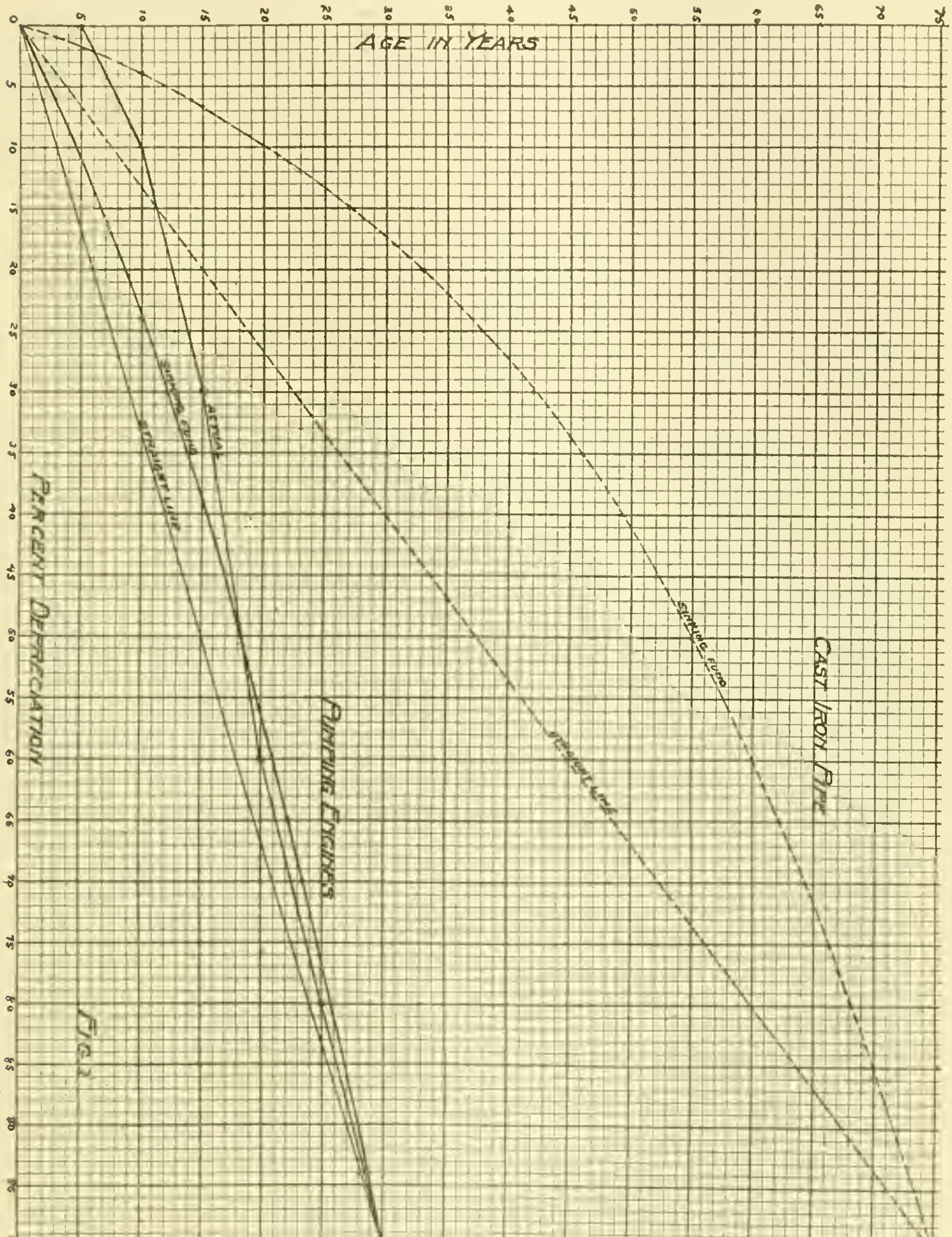


FIG. I.

On Fig. 1, I have plotted the values of an ordinary pumping engine of an assumed life of thirty years, figuring depreciation, first by the straight line method; second by the sinking fund

method; and, third, as it seems to occur in actual practice. The abscissæ represent the percentage of depreciation, and the ordinates the age of the unit.

At zero age, the beginning of the life of the unit, its depreciation is, of course, zero, and when the end of its life has been reached its depreciation is 100 per cent. The proper values at intermediate dates, however, are matters of some complication, as already explained. To use Fig. 1, find the age of the unit in the column of ordinates on the left; then proceed horizontally across the page to an intersection with the particular curve in use; then continue at right angles to the base line, at which point the percentage of value which the unit has lost up to that date will be found. If the straight line method is followed its value at any intermediate date is represented directly by the proportion of the useful life which has yet to elapse. In using the sinking fund method it is necessary to ascertain what sum has accumulated in that fund at the date of appraisal. This deducted from the cost of reproduction gives the value.

This involves a consideration of the characteristics of the sinking fund. It assumes that at the inception of the plant a life period for each unit has been assumed and the annual payment computed, which, with compound interest, will, at the expiration of the period selected, provide a fund sufficient for the renewal of the unit. If this plan has been faithfully adhered to there is at any intermediate date an amount in hand which, if deducted from the original value (or cost of reproduction), will fairly represent the present value. This money is supposed to be safely invested so as to earn interest. Or it may be returned to the stockholders and the plant value as an asset charged off to correspond, or the amount may be used for the retirement of the bonded indebtedness, as is often done.

As a matter of fact, such funds are rarely if ever found in practice. This, however, is immaterial to the appraiser, who uses the method simply as a fair means of reaching present value. It is, of course, simply a question of computing compound interest. The result is a geometrical series, the actual computation of which in any given instance is tedious. Fortunately tables have been prepared giving these values for various periods of years, and at different interest rates, and from these curves have been plotted which render the computations easy and simple. The regular curve in Fig. 1, represents such a sinking fund compounded annually at 3 per cent., as such funds necessarily bear a low rate of interest. If we follow the sinking fund plan we

find that at the age of five years the engine would have depreciated about 6.5 per cent.; at ten years, about 25 per cent.; at fifteen years, about 38 per cent.; at twenty years about 55 per cent.; and so on.

What has the depreciation actually been? Let us assume an ordinary pumping engine of good design and construction receiving intelligent care, ordinary maintenance and repairs being well kept up. Such an engine in the average plant would probably serve its intended purpose for the first five years with no depreciation whatever. In fact, as explained above, it might even be claimed to have advanced somewhat in value. Assuming a growing consumption of water, it might be assumed that after five years it would begin to be necessary to run this pump at excessive speeds, or to pump longer hours, in order to avoid the employment of a night pumping crew. This reduced efficiency and increased labor will cause a drop in value which we assume has reached 10 per cent. at the end of 10 years. When the demand finally exceeds a quantity which can be pumped with a single day crew, even under forced conditions, there is a further drop in value. It then becomes necessary to put on a night crew, which handles the service satisfactorily up to the fifteenth year, the value, however, having dropped a total of 30 per cent. As the demand continues to increase, excessive speeds and continuous operation day and night become necessary, at a correspondingly reduced efficiency and increased cost of repairs, which bring the depreciation at the end of twenty years to 60 per cent. At this time it becomes necessary to add another engine, so that the original pump is used only in connection with it at times of maximum demand, or for occasional reserve use. Running only part of the time, and at reduced efficiency, its value, we may say, declines to 80 per cent. at the end of the twenty-fifth year. After this, the wear and tear of essential parts, such as cylinders, valve seats, etc., beyond reasonable repair, together with the ordinary usage to which it may reasonably be expected to be subjected, such as occasional neglect and overwork, have practically ended the pump's value for regular service. It is, however, kept in position and occasionally operated for a further period of five years as a reserve. By this time it has practically worn itself out and the space is needed for other and more modern units of larger capacity. If the unit can safely be assumed to still have a scrap value greater than its cost of removal, such value should be deducted from the cost of reproduction, and the depreciation figured on the remaining

value. It is doubtful, however, whether such possible scrap value should be given much weight, as it is impossible to predict the actual condition of the pump, and its antiquated design would probably limit the chances of advantageous sale.

In Fig. 1, the line marked " actual " is intended to represent this story of depreciation. It will be noticed that at all times the pump's value is above that indicated by the straight line method, during its earlier life materially so. While the sinking fund curve does not accurately represent its value, it approximates it much more nearly than the straight line.

In Fig. 1, a similar comparison between the straight line and sinking fund methods as applied to cast-iron pipe of an assumed life of seventy-five years is also shown. The marked difference between these methods when applied over a long period of years is here emphasized. For instance, at twenty years of age, the pipe, according to the sinking fund curve, has depreciated but 10 per cent.; at thirty-seven and a half years, half its life, only 25 per cent.

It will readily be seen, therefore, that the method to be selected is of great importance when considering the long-lived features of the plant.

How does the depreciation of a system of cast-iron mains actually occur? In its earlier years it serves its purpose efficiently, the consumption being small and the pipe practically free from incrustation. As the years go by, the pumpage increases, the friction losses grow, and increasing incrustation reduces the capacity of the mains and adds still further to the friction head. Furthermore, increased brittleness is found, and there are breakages here and there. No very definite values, however, can be figured for these losses in value, but it is evident that in a general way they are small during the earlier years, and increase more and more rapidly towards the end, evidently following reasonably close to the sinking fund curve.

Similar analyses might be applied to the other features of the plant, the building, boilers, reservoirs, standpipes, valves, hydrants, etc., but in practically every case it will be found that the depreciation is low at first, increasing later, and is, therefore, better represented by the sinking fund curve than the straight line.

Having then the cost of reproduction of each feature of the plant, its assumed life, and a sinking fund curve to correspond, we may at once arrive at a value for that unit. The sum of these is the present value of the entire physical plant. Care must be

taken, however, to insure that such computed value is in harmony with the physical appearance, performance and usefulness of the unit as noted by careful inspection at the time of appraisal.

As indicating how such computations work out, the following recent figures are given: A water system, built in 1888 at a cost of $61 443, could be duplicated, including worn-out parts, in 1907, for $63 893. The present value of the remaining physical property is $38 478. The depreciation in nineteen years has, therefore, been $22 965, or 37.3 per cent. of the original cost. This covers not only the actual physical depreciation, including the abandonment of certain worn-out parts, but allows for the present higher cost of duplication. This amount would have been available at the end of the nineteen years if the sum of $914.24 had been set aside each year as a sinking fund, and compounded annually at 3 per cent. interest. This sum, which is 1.488 per cent. of the original cost, should, of course, have been considered as one of the regular and legitimate items of operating expense. Had this sinking fund been continued it would have wiped out the entire original cost in 18.35 years more, a total of 37.35 years, which may be taken as the average life of the plant as a whole. The depreciation included in this case the abandonment of two settling basins and one filter and filter house. As the worn-out parts had been fully cared for, only $681.90 of the original sinking fund payment then remained in force.

During the nineteen years in question, betterments and extensions were made, bringing the original cost up to $81 363, and the cost of duplication to $87 965. The appraised value of the whole in 1907 is $59 691. Detailed consideration of each of the units of the system showed that the total annual charge to sinking fund to cover present depreciation should now be $982.68, assuming that the entire amount which has previously accrued to the credit of sinking fund is available and is continued at compound interest. If, however, a fresh start is made, on the basis of the reduced valuation, then the annual payment to sinking fund to make good that value (not the original cost or cost of duplication) must be increased sufficiently to make up for the missing interest of the earlier fund, now charged off. In the case referred to, this payment became $1 583.48 per annum, or 2.86 per cent. on the present value, which amount would repay that value in 25.7 years more.

The above figures bring out what have been claimed to be the weak points of the sinking fund plan. If rigidly carried

out it will do all that is claimed for it, in justifying a higher value for the plant in its earlier years and in reducing the annual cost of operation as a result of the low payments to sinking fund. But when no such fund exists,— as is nearly always the case,— complications seem to arise. After the purchaser has taken over the plant at the figure thus arrived at, he must, in order to carry out the scheme, set aside an additional amount, equal to the previously accrued sinking fund, and continue it at compound interest, besides keeping up the original payments to sinking fund. If he does not do this, and he rarely or never does, then he must establish a new and increased annual sinking fund. Not only has he paid what appears to be high price for the plant, but he must take care of the entire balance of depreciation in the few remaining years of its life. It has been questioned, therefore, whether a wholly imaginary plan, which imposes such obligations upon the purchaser, is altogether fair.

To this it may be answered that the mere fact that the plan involves bookkeeping methods which may not actually have been followed, should not be an objection so long as the results are just and fair to both parties, and in reasonably close harmony with the actual depreciation. The purchaser should expect to put himself in the place of the original owner, assuming all his responsibilities and obligations, one of the most reasonable and necessary of which is the maintenance of such a sinking fund. Whether such a fund is actually in hand or not, the owner does his full duty when he allows its computed amount to be deducted from the cost of the plant. Should the purchaser be unable or unwilling to replace this sinking fund so as to continue and carry out the scheme, he must accept the consequences of such action by making provision for an increased future sinking fund.

Having thus fixed the physical value of the plant, it is in order to inquire whether good reasons exist why this value should be either increased or decreased. Are any of the other considerations hereinbefore referred to applicable to the case under consideration, particularly the "going" and "franchise" values?

As a preliminary to further discussion, we may pass at once to the consideration of earnings. If the plant is not earning a profit, or has reasonably certain prospects of doing so in the immediate future, it is unnecessary to consider either the "going" or "franchise" value. In such cases, which are by no means uncommon in the smaller cities where there is often little

or no growth, the company is usually more anxious to sell than the city is to buy. Having been a losing proposition, the owners are anxious to get the plant off of their hands. The city, on the other hand, being usually familiar with the situation, is in no hurry to take over the plant, and will only do so on a valuation commensurate with the financial returns which may be expected, due allowance, of course, being made for such public uses of water as for fire hydrants, street sprinkling, flushing of sewers and gutters, public buildings, fountains, etc. Under such circumstances, in order to have consideration at all, it may be necessary that the price fixed be equal to or even lower than the fair physical value. This, of course, is unfortunate for the owners, but there seems to be no fair remedy. They have simply gone into an unprofitable venture and must meet their losses, just as they would have been entitled to absorb the profits had the opposite been the case. To put it another way, the actual worth of the service to the people fixes a maximum beyond which no estimate of value, however logical, can go.

It has been argued that " going" value may exist even when a plant is losing money. It is of course true that a plant with some business is worth more than one with little or none. But to be worth even its physical value it must be earning enough to meet all legitimate operating expense, together with interest on that value, and a sinking fund for depreciation; or such earnings must be reasonably certain in the not too distant future. If, however, we start with a value based on earnings (which in the case of a losing plant would be below the physical value), then something might be added for " going " value.

Assuming, however, that there is a clean and legitimate profit, present or immediately prospective, it may be in order to consider both the " going " and " franchise " values.

Referring back to Method No. 6, of valuation, with its further reference to Method 4, the author would base " going " value upon the losses sustained in the legitimate operation and maintenance of the plant during its earlier years, up to the time it became self-supporting. Often these losses are shown by the company's books, which, however, should be scrutinized carefully to make sure that they have been correctly kept. Even when the books do not give these figures, the date when the plant ceased to lose money can usually be fixed, and it would not ordinarily be difficult to make a reasonably close estimate of the probable losses previous to that time. Any amounts which can be shown to have been spent directly for

building up the business should also be added. In the author's judgment such a computation does not involve anything like as many difficulties as other methods which have been proposed.

Should worn-out and replaced material be included in such losses? Where such renewals come as a result of natural wear and tear, they are supposed to be covered by the annual charge to depreciation or sinking fund. But where it results from poor design or construction, or unsuitable material, and is in no way necessarily incident to the conduct of such a business, it should be excluded.

Two cases of such computations, however, appear abnormal:

1. Local conditions may lead to an immediate and extensive demand for water, the company making the connections as fast as they can be handled, very soon reaching a large and profitable consumption. In such cases the cost of getting to an earning basis would be a minimum, whereas the value of such business would appear to be a maximum.

2. Take also the opposite case, where the town is slow and conservative, and where there may be good cisterns and wells which the people are in no hurry to abandon. In this case it may be many years before a self-sustaining business is established, and many more before the profits are of any magnitude. In such cases the earlier losses would be a maximum, and the business when secured would be of small value.

In the first case, it may be said that the business thus favorably secured was due less to special efforts on the part of the company than to the favorable local situation. Having resulted from the efforts and needs of the people themselves, and the growth and development of the community, the principal value comes from, and should remain in, the city itself. This is fair even though the presence of an efficient water system may have contributed to that growth.

The second case is again a question of net earnings. If these do not warrant an addition to the physical value, then the city could not afford to pay for same, nor would it be proper for an appraiser to make such an award. If, however, these earnings have finally become substantial, and there is reasonable prospect that they will continue to advance, the author sees no objection to a material award for "going" value, equaling possibly the full amount of the losses which have been sustained. The owners have bravely fought what was for a long time a losing battle, but having finally triumphed, they should not be barred from an opportunity to recoup themselves without due reward.

Suppose that after the plant has become self-supporting the customers continue to increase, and that money is expended in getting them as before. Also that at the time of appraisal the connected business is many times greater than originally sufficed to merely pay expenses. Should not this justify an increased "going" value?

It would seem so, and this value might be assumed to bear the same ratio to the "going" value at the time the plant first met expenses that the present number of connections bears to the number then.

On the other hand, something may be said against such increased value. The system now being self-supporting, it might be argued that the increased business has really cost the company nothing. If money was still being spent for this purpose, the owners, having no ground to assume that it would ever be repaid, must have felt satisfied that it would be fully returned in profits during the unexpired portion of the franchise. In most cases the business has increased as a result of the development and growth of the community, for which the people deserve more credit than the management. Furthermore, such a value verges dangerously close to one based on earnings, which may be forbidden. To which it may be added that in such cases the greater profits have long since paid off the earlier losses, which form our basis of "going" value.

We come now to the "franchise" value, or value based on earnings. This value, of course, depends upon three contingencies:

1. That the wording of the franchise permits its consideration.

2. That there is a net legitimate profit, after due consideration has been given physical and "going" values.

3. That the franchise has still a considerable period to run, during which such earnings may reasonably be expected to continue.

Assuming all these conditions to exist, however, it is fair to add a further value based on earnings. The profits for the preceding years should be looked into very carefully, and all the matters mentioned in Method 10 above should be given due consideration so as to get at a fair basis and average of these earnings. Interest should be computed upon not only the physical, but the "going" value of the plant, if such a value has been fixed. With this data in hand it should be possible to predict with reasonable accuracy the probable earnings for each year of the unexpired portion of the franchise. These should

then be reduced to their present value, figuring a low rate of interest, and the whole added to the sum of the physical and "going" values.

In those states, notably Illinois and California, where the law gives municipalities the right to regulate water rates, conditional only on earning a fair return on the investment, it would seem that no water plant could ever have a "franchise" or "earning" value.

Earlier in this paper (see page 339) there was given a list of considerations which would affect the value of the plant, tending in some cases to increase that value, and in others to lower it. What effect, if any, would these have on the value established as above?

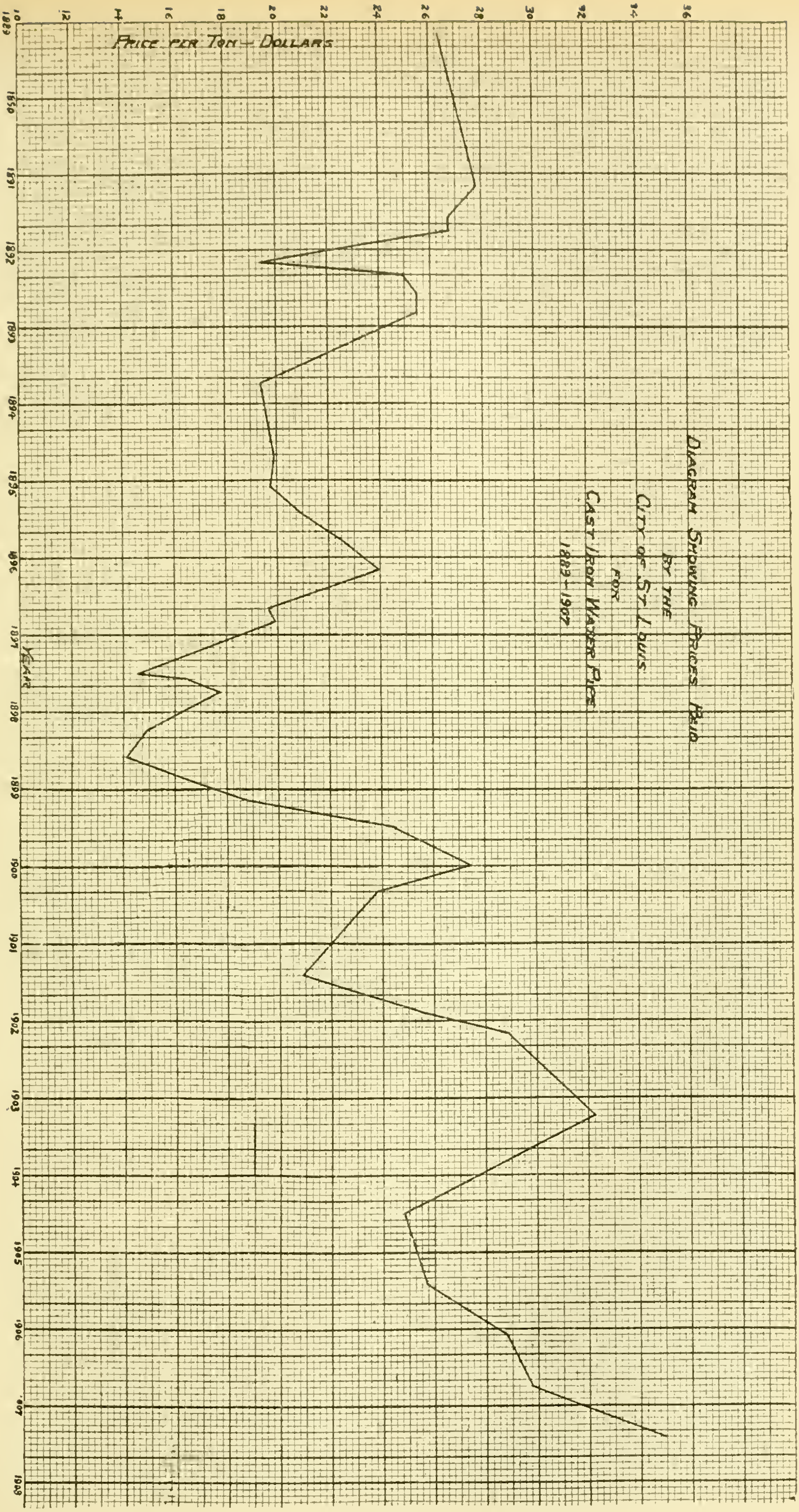
Taking up first those items which might increase the value above the original cost, it is evident that items one and three, covering the advance in cost of construction, and the fortunate suitability of the plant for its work, are fully cared for in the valuation based on cost of reproduction less depreciation. The second item — that resulting from the profits earned — is taken care of by the earning value.

As to the items which might decrease value, it is evident that the first four, namely, wear and tear, reduced cost of reproduction, poor design, and growing unsuitability for the work, are all cared for in the estimated cost of reproduction less depreciation. Item 5 *a*, which concerns the quantity and quality of the water supply, might properly be considered both as affecting the suitability of the plant for its work,— in other words, its physical value, — and also under earnings, as these would undoubtedly be affected by such a consideration. The remaining items, 5 *b*, *c* and *d*, poor management, uncertainty as to the future, and probable rates, all receive due consideration under the value based on earnings. It would seem, therefore, that the method outlined takes care of all possible contingencies.

To these figures there should usually be added the value of tools, material, repair parts and supplies on hand as shown by verified inventory. This should be again verified or revised by the parties themselves at the date of actual transfer.

This latter total is the sum which, in the author's judgment, should be fairly recommended as the proper value of the plant.

In computing original and present costs it is important to know the ruling prices of cast-iron pipe at various dates. Through the courtesy of Mr. W. E. Rolfe, of the Water Department of the city of St. Louis, I have secured the prices paid by that muni-



Price per Ton — Dollars
Diagram Showing Prices Paid
by the
City of St Louis
for
Cast Iron Water Pipe
1889-1907
Years

FIG. 2.

cipality for eighteen years back. These are shown in the accompanying table and chart, Fig. 2. The quantities purchased, and the large sizes and weights employed, give such a purchaser a decided advantage over the ordinary buyer. This should not be forgotten when making comparisons.

After all has been said and done, however, it must not be forgotten that such a value is not capable of exact mathematical determination. The best that can be done is to place it within comparatively narrow limits. When it is necessary to fix upon a definite figure, the appraiser must exercise his best judgment as to disputed or hazy points, often arbitrarily it may seem. But when he has done this, fairly, impartially and in good conscience, in the light of all facts and equities as he sees them, he need fear to look no man in the face.

There has been much loose thinking in these matters, for a share of which we engineers are not altogether without blame. Cases are on record of gross errors both ways, where plants have been unloaded on to communities at inflated values, and others where the cities have practically confiscated them. Capital invested in legitimate water-works enterprises is entitled to the same protection and return as in other directions. Such investments should, if possible, be made attractive to capital; they should be safe and sound. Unfortunately this has not been the case for some years. Bonds secured solely on the plant itself, whether municipal or private, are extremely hard to market, and it is becoming more and more difficult to organize private companies to undertake water franchises. It is the hope of the author that this discussion may assist in bringing about a clearer and a fairer understanding of this interesting matter from every standpoint.

Table showing Estimated Life and Depreciation of Apparatus, Machinery, etc., Compiled from Various Sources by William H. Bryan, M.E., St. Louis.

REFERENCES.

1 *Engineering News*, May 4, 1899, Los Angeles, Cal.
2 W. Kiersted: Proceedings American Society of Civil Engineers, 1897.
3 Proceedings American Society of Civil Engineers, 1897.
4 Cincinnati Electric Light Convention, 1902, *Electrical World and Engineer*, August 9, 1902.
5 Iowa Electrical Association, in *Iowa Engineer*, July, 1906.
6 The author.
7 Dawson's "Engineering and Electric Traction Pocket Book," in *Iowa Engineer*, July, 1906.

8 John W. Alvord: Proceedings American Water Works Association, 1903.
9 N. S. Hill: *Engineering Record*, June 8, 1901.
10 Rob't Hammond: *Engineering Record*, June 15, 1907.
11 Benezette Williams: Galena, Kan., appraisal, 1905.
12 W. Kiersted: Galena, Kan., appraisal, 1905.
13 Chicago City Railway, *Street Railway Journal*, December, 1898.
14 W. H. Rosecrans, Galena, Kan., appraisal, 1905.
15 Prosser in *Engineering News*. Vol. XLVII, p. 425.
16 B. L. Dodge, Oak Park, Ill.: Appraisal, Mt. Vernon, Ill., Water Works, 1906.
17 Chas. B. Burdick, Chicago: Appraisal, Mt. Vernon, Ill., Water Works, 1906.
E. N. *Engineering News*.
E. R. *Engineering Record*.
M. E. *Municipal Engineer*.

Material.	Life in Years.	Depreciation. Per ct. per yr. Straight	Sinking Fund.	Authority.	Remarks.
Entire Systems:					
Electric Light		10		4	Am. Inst. E. E.'s.
"	12.33	8		4	N. Y. Edison Co.
			3	4	English municipal Engineers.
"		5		4	Mass. Gas & El. Com.
"		7.5–10		4	Motions made but not adopted.
"	12.5, 14			5	
"	16.66, 20				
		6.4–7.4		6	
Water Works		1.465		1	Los Angeles, Cal., 29.3% in 20 yr.
"		1.667		2	Kansas City, Mo., 33.3% in 20 yr.
"		1.1		3	Tuttle, 22 % in 20 yr.
"		.62		*E. R.*, 7–23–'04	Quincy, Ill., 18.7 % in 30 yr.
"		2.47		*M. E.*, May, '03	Valparaiso, Ind., 37.1% in 15 yr.
"		.86	1.58	*E. N.*, 4–23–'03	Mobile, Ala., 12 % in 14 yr.
"	37.35	1.95	1.49	6	Washington, Mo., 37.3% in 19 yr.
"	40			3	C. Palmer.
"			1	*E. R.*, 6–1–'01	Court Contra, Costa, Cal.
"	37		1.50	3	F. C. Coffin.
"	31		2	3	Haverhill, Mass.
"		1.99		6	Rich Hill, Mo.
"		2.21		6	Galena, Kan.
"		2.91		6	Mt. Carmel, Ill.
Water, Gas and Elec. Light Plants (Average of 52)		2.784		*E. N.*, 5–7–'03	14th An. Rep., U. S. Com. of Labor.
Arc Lamps	8			5	
" "	12–15			6	
Belts	3–4			7	

Material.	Life in Years.	Depreciation. Per ct. per yr. Straight	Sinking Fund.	Authority.	Remarks.
Boilers	6–23. Av. 15			8	Average of 32.
,,		5–7		9	
,,	15			15	
,,	20–30			2	
,,	20			10	
,,	10–12.5			7	
,,	14–15			5	
,,	25			11	
,,	30			12	
,,		8		13	
,,	14.3–25			6	
,,		2.5–4		14	
,,		6		16	
,,	25			17	
Bonding, Track		8		13	
,, ,,	10–16			7	
Bridges					
Iron		5		9	
Masonry		1		9	
Trestle		15–20		9	
Buildings					
Brick		2		5	
,,		2		9	
,,	40			15	
,,	25–40			6	
,,		7		14	
,,	60			10	
,,	50–100			7	
,,	25–33–50			5	
,,	30			11	
,,	30			12	
,,		5		13	
,,		3.5		16	
,,	35			17	
Wooden		5		9	
,,		4		14	
,,	15–30			6	
Cables, Feeder	20–35			7	
Cars	15–25			7	
,, Bodies		7		13	
,, Motors	12.5–20			7	
,, Trucks		8		13	
Condensers		7–10		9	
,,	12.5			5	
Conduits		3–5		9	
Converters					
Stationary	15			10	
,,	15–20			7	
,,	12.5			5	
,,	10–12.5			6	
Rotary	10–12.5			7	
Engines					
Steam		4–6		9	
,,	25			10	
,,	15–25			7	
,,		8		13	
,,	20	5		6	
Pumping	20–25–30	5		6	
,,		3–10		9	
,,	15			15	
,,	20–30			2	
,,		4.7		14	
,,	25			10	
,,	10			5	Boiler feeds, etc.
,,	3–36. Av. 21.3			8	Average of 50.
,,	25–30			11	
,,	30			12	
,,		2.5		16	
,,	30			17	

Material.	Life in Years.	Depreciation. Per ct. per yr. Straight	Sinking Fund.	Authority.	Remarks.
Engines & Generators					
Belted	10–20			7	
Direct connected	12.5–25			7	
Filters, Water	15–20			6	
Gear Cases		20		13	
Generators	15			6	
,,		7–12		9	
,,	25			10	
,,	10–20			7	
,,		3		13	
Hydrants, Fire	25–35			6	
,, ,,		2		1	
,, ,,	40			11	
Insulators					
Pole Line		12		13	
Trolley		7		13	
Meters					
Electric	10			10	
,,	10			5	
,,	10–12.5			7	
,,	10			6	
Water		3		1	
,,		2.1		*E. N.*, 4–23–'03	Mobile, Ala.
,,	20			11	
,,	20			6	
Motors					
Car	12.5–20			7	
Armatures		33		13	
Commutators		33		13	
Controllers		4		13	
Fields		12		13	
Paving,					
Asphalt		7		13	
Brick		7		13	
Cedar Blocks		16		13	
Granite		5		13	
Macadam		6		13	
Pipe					
Cast Iron	50–75			6	
,,	68			*E. R.*, 8–28–'97	Los Angeles, Cal.
,,		1.25		1	Do., Good Soil.
,,		2		1	Do., Poor Soil.
,,	20–60			3	R. Hering.
,,	25–60			2	
,,	70			15	Gas Mains.
,,	Over 50			3	Pearsons.
,,		1.14		14	
,,		1		16	
,,	100			8	
,,	100			17	
,,	80			11	
,,	75			12	
Service	10			6	
,,		2.5		1	
,,		5		16	
Wrought Iron	30			11	Underground.
,,	20			12	
,,	15–20			6	
,,		5		16	
In Plant	15			15	
,,	25			10	
,,	14–15			5	
,,	20–30			6	
,,		10		16	
Pole Line	15			6	
,, ,,		12–15		9	

Material.	Life in Years.	Depreciation. per ct. per yr. Straight	Depreciation. per ct. per yr. Sinking Fund.	Authority.	Remarks.
Poles					
Iron		4		13	
Wooden		8		13	
& Cross Arms	10–12.5			5	
Rails		5.5		13	
Reservoirs	50–75			2	
,,	40–75			6	
,,	100			17	
Standpipes	25–30			6	
,,		4		14	
,,	40			11	
,,	30			12	
Storage Batteries	9–11			7	
Switch Boards	10			5	
Ties		7		13	
Track		8–12		9	
,,	7–13			7	
Trolley Line	12.5–25			7	
,, ,,		5		13	
Turbines, Water	11–14			7	
Valves	25–35			6	
,,	40			11	
Wire, On Poles	25			5	
Wiring of Cars		8		13	

Table showing Prices Paid by the City of St. Louis for Cast-Iron Pipe Delivered at Yards in St. Louis since 1889, per Ton of 2 000 Lb.

Date of Order.	Sizes in Inches, and Quantities in Tons. 3	4	6	8	10	12	15	20	30	36	42	48	Price.
——'88													$26.45
2–19–'89			330	75		395							26.33
4– 2–'91						590							27.84
7–28–'91			125			515							26.75
8– 9–'91			1 428	130		910	6			26			26.75
2–10–'92			35			55		1 000	210				19.47
4–25–'92						60					65		24.95
7–30–'92			1 440	40		720							25.48
10–19–'92						5				685			25.48
9–18–'93	10	30	1 400			1 560		2 035		450			19.40
8–21–'94			810			810	10	1 780	3 350	380			19.94
4– 1–'95			8			12			3 307	1 300			19.85
5–23–'95		8	787			55							20.96
9–20–'95								950	5 400				22.47
2– 8–'96	25	75	1 550	15		1 200							24.00
8–12–'96			900			1 450		350					19.64
10–12–'96			5			30		155	2 915	6 905			19.94
6–10–'97			750		6	1 400		1 044					14.57
7–12–'97											53		16.50
9–29–'97				30		70	50	1 200	100				17.84
3–31–'98			575			1 500	15	1 085		25			14.97
7–25–'98			600			1 330		1 405				15	14.08
2–20–'99			650			2 700		350	400				18.80
6–16–'99			600			1 075		1 120		1 305			24.40
4–23–'00			1 000			2 600		2 050					27.49
8–14–'00			12			28				5 350			23.84
5– 4–'01			700			1 620		2 110	820	950			22.93
3– 8–'02			1 145			1 025		2 345	2 770	2 015			25.83
5– 1–'02			830	175	225	550				1 580			28.93
3–30–'03	25												36.25
3–30–'03		15	1 390			1 190	30	1 175	700				32.25
6– 4–'04	70												28.00
6– 4–'04		50	1 140			860		1 160	20	3 200			24.90
5– 1–'05	12												29.45
5– 1–'05			1 160										27.45
5– 1–'05						1 360							26.45
5– 1–'05								375	840	153			25.70
1–29–'06			2 200			2 650		1 650					28.90
9–15–'06			1 350										30.75
9–15–'05						200		1 050					29.80
5–14–'07	24												39.50
5–14–'07			1 430			1 075		1 460		2 161			35.00

DISCUSSION.

Mr. Robert Moore. — A large part of the difficulty in making the appraisements of which Mr. Bryan speaks is due to the obscurity of the ordinances under which they are made. As a rule, these ordinances, in speaking of the sum to be arrived at and paid by the municipality, use the word "value," a word which is used loosely in several senses, and which, with rare exceptions, is not properly applicable at all to cases like this.

In economics, as in business, value means "power in exchange"; that is to say, it is the amount in goods or in money for which the article in question will exchange in a free, open and competitive market. But the taking of a water-works plant by a city under the provisions of an ordinance is a forced transfer without competition, to which the rules of the open market do not apply. If the market were really free and open the value of the plant would be determined by its earning power, in other words, the amount upon which it would earn and pay interest would be its value. But this method of valuation is usually by express terms excluded from consideration; and when this is done it is better to avoid the use of the word "value" altogether.

An example of how this may be done and all ambiguity thereby avoided is found in an ordinance of the city of Chicago, dated July 15, 1903, authorizing the Illinois Telephone and Telegraph Company to construct, maintain and operate its tunnels under the streets. Section 6 of this ordinance provides that after twenty years the city may terminate the grant and take over the property, and provides also for a payment to the company in a clause which reads as follows:

> "In case the city council shall decide to terminate the grant and take over the property as aforesaid, then the city shall pay therefor in cash the then cost of duplication, less depreciation, of said tunnel appliances and property, with 5 per cent. addition thereto as compensation for the compulsory sale, but there shall be no allowance for earning power or franchise values."

Under this clause the appraisers will know exactly what to do, and in this respect the ordinance may well serve as a model for other cities.

Mr. Edward Flad. — The appraisal of a water-works plant, where the conditions governing the appraisal are not definitely specified in the franchise, or in the instructions of the court, should take into consideration the two elements upon which its value depends. First, the physical value, after making allowance

for depreciation; and second, the net earning capacity, both present and future, which will include the so-called "going" value, and "franchise" value.

In attempting to apply rigid rules to any particular case, the results will often be found to be so far at variance with the generally accepted notion as to the value of the plant that the assumptions must be changed until the results seem fair. This is not a highly scientific method but will often avoid absurd conclusions.

The writer believes that depreciation should be estimated at a fixed annual amount representing the annual charge for a sinking fund sufficient to replace the portion of the work referred to at the end of its assumed life, and not, as Mr. Bryan suggests, by estimating what he calls the "actual value," which takes into account the economical value at the time of the machine or structure. This method is difficult of application, leaves room for considerable difference of opinions, and appears to have no particular advantage. Depreciation as estimated by the sinking fund merely means that so many years of the life of the machine or structure have expired, and that the best modern practice requires an equal annual charge for sinking fund purposes.

There are in any specific case so many modifying conditions which materially affect the value of a plant that it is no wonder that engineers of equal honesty of purpose will arrive at conclusions so far at variance with each other that the layman is apt to imagine that the engineers have been unduly influenced by the interest of their clients.

Mr. Bryan has given a thorough discussion of the various modifying circumstances which must be considered. It would be interesting to have him give in detail the application of his arguments to the particular case which he cites in which he states he acted for "both parties in interest, the city and the company," and the writer suggests that Mr. Bryan add such a statement to his paper.

In making a valuation of a water-works plant, much of the difficulty which one encounters is due to the fact that the franchise either makes no provision for the appraisal or else is not definite in specifying the various elements which shall control.

This leads one to inquire into the shortcomings of the ordinary franchise and the manner in which they can be overcome.

In the past, franchises have been granted in which the element of risk was unnecessarily great. The promoter under-

took to supply water under rates that were fixed, or at least were maximum charges; no limit was placed upon the profits, and the public in general had no means of obtaining information upon the financial operations of the company and was not supposed to have any interest in same.

It seems to the writer that a more mutual responsibility, a removal of part of the element of chance, and a mutual enjoyment of such profits as may arise, would result in less friction between the company and the city, better and more satisfactory service, and would increase the value of water-works securities, which have, in recent years, become almost unsalable. The principal assumptions on which such a water-works franchise should be predicated which have a bearing upon the financial questions involved are as follows:

(1) That the parties investing their money shall be entitled to make an annual profit equal to a definite percentage on the investment, and no more.

(2) That the water rates shall be fixed so as to obtain sufficient revenue to provide for operating and maintaining the works, pay a definite interest on the investment and set aside a fixed amount annually for sinking fund charge.

(3) That the city may, at stated intervals, purchase the works by paying a price which will insure to the investors a return of all of the money invested and interest on same to the time of purchase at the rate agreed upon, and, in addition, a reasonable profit.

The actual rates of interest will, of course, depend upon the size and location of the town and upon the degree of risk involved in any particular case.

As illustrating the application of the above assumptions to a particular case, the writer submits herewith the general terms of a franchise such as, with slight modifications, he recently submitted to a small town in Illinois, in the belief that, as compared with the form of franchise usually granted, the one herewith proposed better protects the interests of both parties, removes in part the element of risk, insures increased value of the securities to be issued, enables the city to participate in the profits, invests the city with a beneficial element of control and establishes a mutually friendly relationship, which cannot but result in the peace of mind of the public which has, in recent years, been prone to unduly villify all public utility corporations.

The system of water works referred to was estimated to cost about $50 000 all complete, ready for operation.

The conditions which it was proposed to incorporate in the franchise are as follows:

(1) Within ninety days after the franchise is granted the company is to submit plans, specifications and estimate of cost for approval of the city council.

(2) When plans, specifications and estimates of cost are approved, the company shall commence work within thirty days and have the plant completed and in operation within twelve months.

(3) Failure to submit satisfactory plans within ninety days, or to have the works completed and in operation within twelve months of approval of plans, specifications and estimates, shall work a forfeiture of the franchise and all the rights and privileges granted therein, if the city council shall so elect.

(4) The city to pay a fixed amount per year, say $4 000, for fire service and for water for public drinking fountains and street sprinkling. A portion of said payment, sufficient to pay 6 per cent. on the bond issue, to be payable directly to the bond holders in semi-annual installments, and a special tax to be levied for its payment.

(5) A schedule of water rates to be provided.

(6) The city to grant the exclusive right to lay pipes in streets, alleys and public places for the purpose of furnishing water.

(7) The company shall have the right to issue bonds equal to the estimated cost of the work, and an equal amount of stock, bonds to bear 6 per cent. interest, payable semi-annually.

(8) All plans for improvements or extensions, unless the cost of same is to be paid out of revenue, must be approved by the city council, and after such approval the company may issue additional bonds equal to the estimated cost of the work and an equal amount of stock.

(9) At the end of each fiscal year the company shall file a sworn statement with the city council of all income and expenditures, showing separately the amounts expended for operation, repairs, improvements and extensions, and for interest, dividends, sinking fund and taxes.

(10) The company shall be allowed to declare dividends equal to 4 per cent. annually, cumulative on all stock issued, all excess earnings to be set aside for sinking fund, invested in bonds of the company or applied to repairs, improvements or extensions.

(11) The city to have the right to purchase the works at the end of the first five years, or at the end of every five years thereafter, upon the payment of an amount as follows:

The face value of all bonds outstanding, with 10 per cent. added thereto, and with all accrued and unpaid interest plus all deferred or unpaid 4 per cent. dividends on stock, as provided for herein.

When the works are so purchased, all of the stock and bonds shall be delivered to the city and it shall assume all current indebtedness and receive all monies on hand at the time of transfer.

(12) It is the intention to fix the water rates so that after paying for all operating expenses and repairs, the company will be able to pay 6 per cent. interest on the bonds, dividends equal to 4 per cent. on the stock, and set aside 2 per cent. annually for the sinking fund. Either party may call for a revision of the existing water rates by notifying the other party in writing between the first and fifteenth of January of any year.

(13) All questions which may arise as to water rates, improvements or extensions, or the estimated cost of same, or as to the purchase price, if the city decides to purchase, shall be decided by mutual agreement of the company and the city council; or failing to so agree, each party shall, within ten days, on the demand of either party, appoint an arbitrator, the two to select a third party; or, failing to so agree upon the third party within twenty days, the said third party to be appointed by the judge of the circuit court of ——— on application of either party. The three parties so appointed shall form a board of arbitration, and the findings of any two of the three arbitrators shall be accepted as final. In every arbitration each of the three arbitrators shall be allowed $25 per day and expenses. The charge per diem and personal expenses of the third arbitrator shall be paid by the party calling for the arbitration. All other expenses of every arbitration shall be divided equally between the two parties. Only such expenses as are approved by at least two of the arbitrators shall be allowed.

(14) The company agrees to use its best endeavors to operate the works in a manner satisfactory to the city; failing so to do the proper remedy is purchase and operation by the city or the resale to some third party.

(15) The franchise to continue in effect until such time as the works are purchased by the city, but not exceeding nine hundred and ninety-nine years.

(16) Any citizen shall have the right to subscribe for the bonds and stock of the company before the work is begun, 40 per cent. of the bonds and stock to be prorated among the subscribers who are citizens of the said city, the balance to be

distributed as may be directed by the party to whom the franchise is granted. For every \$1 000 paid in by a subscriber there shall be issued to him \$1 000 in bonds and 10 shares of stock of the par value of \$100 each, full paid and non-assessable.

In the terms of a franchise, as suggested, the time for completion of certain portions of the work, as well as the amount of payment by the city and the rate of interest allowed, would, of course, be fixed to suit the particular case. Other questions, such as the right to grant an exclusive franchise, or the restraining value of same, if granted; also the legal right to issue bonds and stocks under the conditions stated, would have to be considered.

The writer submits the above for the purpose of starting a discussion on the subject of franchises, believing that the defects in franchises as usually granted are largely responsible for the difficulties encountered in making equitable appraisals when purchase is contemplated by a city.

Mr. S. Bent Russell. — In discussing the paper of Mr. Bryan, for the sake of brevity the writer will consider only the case of a water-works plant which has been running some years under a franchise which will not expire for some years. Moreover, he will not attempt to discuss all the points that might arise in such an appraisal, but will only take up a few such points that seem to him of special interest.

Before attempting to decide on a fair purchase price, it is best that we should first consider its value from several different aspects. In order that we may understand the terms we are using, before proceeding with the discussion proper, the following table is given:

A. Fair Purchase Price	B	Physical value, or value based on cost of reconstruction. (Mr. Bryan's 5th, nearly.)	M — Cost of reconstruction. N — Age of plant. O — Probable life. P — Market value as second-hand material.
	C	Book value or capital invested as shown by a proper system of book-keeping. (Mr. Bryan's 8th, nearly.)	Q — First cost of plant, real estate, etc. R — Amount charged off for depreciation of plant. S — Profits or losses made by increase or decrease in values of machinery, etc., since the plant was built.
	D	Earning value, or value considered as an investment. (Mr. Bryan's 10th, nearly.)	W — Present net earnings. X — Additional capital required. Y — Future net earnings up to expiration of franchise. Z — Physical value of property at end of franchise.

Items B, C and D in the second column are the respective values obtained by three different points of view. B and C might be grouped together under the head of tangible value. The different values above mentioned are not to be added together, understand, but will each have weight in the final decision. These values are based on the data indicated in the third column of the table. The table will be readily understood in its main points.

Let us now pass to the question of depreciation. We find that item R, the amount charged off for depreciation, is a factor in finding the book value C. What the amount should be is one of the questions raised by Mr. Bryan. Age and probable life enter in. The method generally adopted by engineers is to assume a sinking fund made up of equal annual payments with compound interest, the payments being of such amount that the fund will equal the original cost of the plant at the expiration of its life, less its final salvage value. The writer believes this method to be based on the general practice, where bond issues call for a sinking fund, of requiring equal annual payments to the fund. It is the writer's opinion that, all things considered, this is the best plan in use of arriving at a proper amount to charge off for depreciation.

We see, however, that this method of arriving at depreciation depends on very arbitrary assumptions. Why should we assume equal annual payments to sinking fund? Would it not be more fair to have the annual payments gradually increasing, because the revenue of a water-works plant should gradually increase from year to year? — and it would be easier to have the annual payments more nearly in proportion to the revenue.

If we should adopt a sinking fund made up of gradually increasing annual payments with compound interest, the depreciation at the end of ten years of a thirty-year life would be considerably less than when equal annual payments are assumed as in the usual method. The curve of depreciation on a diagram like Mr. Bryan's would more nearly approach the line which he assumes to represent the actual depreciation.

We will now take up item B of our table called the physical value. The main factors in its determination are M, N and O of the table. Having ascertained the cost of reconstruction at present prices, we must deduct some value depending on the age of plant, having in view its probable life.

There would seem to be no fairer way to do this than by the sinking fund method discussed above. The writer believes,

however, that there is another way that the present physical value of a plant could be arrived at. A steam boiler that has been in service ten years has an approximate market value. Second-hand boilers, engines, etc., could usually be purchased which would be equal in utility to those in the plant under consideration. An estimate might be made of the cost of obtaining second-hand appurtenances and installing them so as to give a plant equivalent to that under consideration. This method would, of course, call for a great deal of judgment and information as to second-hand values. In the writer's opinion, however, this method should receive some consideration from the appraiser in determining the physical value. This valuation is designated as item P of the third column in the table.

Values B and C, if fully worked out with similar assumptions, will give about the same results. Let us say, for the sake of simplicity, that we will adopt B as the fair tangible value.

In summing up as to the tangible value we may say that the present tangible value of a plant is something that cannot be rigorously computed because the depreciation or the influence of age and probable life cannot be computed. It is probable that no two engineers would decide on the same figure, and it is likely that the same engineer would at different times find different values for the same plant. There is no question, however, that the experienced water-works engineer is the one best fitted to arrive at a fair value.

Coming now to the earning value D, or the value depending upon the financial statement of the operating company, it is well to consider two main factors. First, the financial condition of the company at the present time, that is, the amount of its receipts compared with the cost of operation, etc.; and second, the probable financial condition at the time of expiration of franchise.

In November, 1906, the writer made an appraisal of the Marion City Water Works Plant, of Marion, Ohio. In this report he gave a financial table giving the condition in 1906 and the estimated condition in 1915, at which time the franchise expires. The plant was built in 1890. As it is somewhat difficult to determine the basis on which to figure for the future, the writer believes that the method used in the Marion case will be of interest.

In the last five years the street mains had been increased at an average of about 0.9 miles per annum. It was assumed that the mains would continue to increase at the same rate

for the next nine years. This would give in nine years an increase over the mileage of the present system of pipes of 28.6 per cent. It was thought fair to assume that the receipts would in nine years increase more than the mileage of the pipe, and 33 per cent. was taken as the increase. It was thought that the expenses would increase at a less rate than the mileage of pipe, and 25 per cent. increase in expenses was taken. It was assumed that the city bought the plant in 1906 for $220 000 and expended $50 000 at once for additional plant. It was assumed that 8 miles of pipe would be laid in the next nine years, at a cost of $48 500, which was based on the cost of reconstruction of the present pipe system per mile not including force main.

From the above data were found the amount of capital invested in 1915 and the receipts and expenses per annum at that time. The interest was assumed to be 5 per cent. on the investment. It was found that after paying operating expenses and interest there was a balance remaining for renewals or sinking fund, and this balance was found to be considerably larger in 1915 than in 1906. These balances will have to be used first for renewals or sinking fund for renewals, and secondly for another sinking fund if it be necessary. This last fund will be required if the present value of the property is assumed to be greater than the physical or tangible value, because at the end of the franchise only the tangible value may be used.

To make this point clear let us take the case of the Marion plant above referred to. We have assumed $220 000 as the earning value of the property. Now, if the tangible value is only $200 000, at the end of the franchise we ought to get $200 000 for the present plant less the value of the sinking fund for its renewal. This would be a loss of $20 000 in nine years. This would at 3 per cent. call for $1 968.80 per annum.

If the balances left over in the years 1906 to 1915 are sufficient to cover renewals or sinking fund for renewals, and also the amounts required to cover loss on capital ($1 968.80 per annum in the case given above), the value ($220 000) assumed at the start may be considered the earning value of the property.

It is evident that while the earning value of such properties may be computed with some degree of approximation, there is room for wide variations on account of assumed factors.

We have now considered the physical value and the earning value. After deciding on these two valuations we do not add them together by any means. They are simply expressions of the value of the property from two quite different and entirely

independent points of view. If the two values should be equal they may each be taken as the fair purchase price, as by either method of arriving at it the price is fair.

The tangible value (B or C) may be greater than the earning value D or it may be less. From the comparison we may judge whether the property is or is not a financial success. That question having been decided, we must look for guidance as to the final steps necessary to arrive at the fair or appraisal price. In this connection the writer would offer for your consideration the following suggestion:

In arriving at the fair purchase price of such a property as between the present owners and the city, the writer feels that the idea of partnership or joint ownership of the property should be kept in view. When a water works is originally installed, the water company provides the buildings, machinery, pipes, etc., while the city furnishes the streets or right-of-way. We might consider also that the city furnishes the plumbing used in connection with the water works, provides the fire engines and in other ways furnishes its share of the total installation. Considering the city water works as a whole. then, we find that the water company has furnished a part and the city has furnished a part. Therefore, they are joint owners of the concern taken as a whole. It is expected that the water company will, during the life of the franchise, get profits on the operation that will be a return for what it has furnished in the installation. It is expected that the city will get increase in revenue from taxation and advantages in the way of reduced insurance, etc., that will be a return for the part it furnished in the installation. We may say it is assumed at the beginning that both parties will profit by the construction and operation of the water works.

The above-suggested joint ownership argument is strengthened if you believe, as the writer does, that it is the duty of the city giving the franchise to see that the water works is properly managed from its inception and that no money is improperly expended in ill-considered projects or otherwise. The city that has not guarded itself in this way cannot expect to escape the ill effects of its negligence.

Now in applying the above argument at the time of proposed sale we may be able to determine whether or not the water company has received a fair return for what it has furnished, but we cannot so easily determine whether or not the city has received a fair return for what it supplied. If a sale is to be made it would seem to the writer that the aim should be to have each

party receive a proportionate return for what it has provided. Perhaps the fairest way to do this is to divide the profits or loss of operation between the two parties. If the property has been operated to the present time at a loss, the city should be willing to bear part of this loss in acquiring possession of the property. What portion of the loss the city should take is a matter that would be left to the judgment of the deciding party.

We are here reminded of another theory now in use, which is to call this loss, or part of it, the "*going*" *value* of the plant as discussed in Mr. Bryan's paper.

Let us now assume that the partnership theory is to be allowed and that we have found the tangible value to be $200 000, while the earning value is $220 000. It would seem not unfair to call the "difference" profit, and divide it in some proportion between the seller and the purchaser. Let us say three fourths should go to the seller, making the purchase price, $215 000. Had the earning value been only $180 000, on the same basis the seller should bear three fourths of the loss, making the purchase price $185 000.

The idea of partnership crudely expressed above is given merely as a suggestion to those who are studying the subject. The writer believes, on the whole, that fixed rules cannot be followed in making appraisals, but he thinks it a great advantage to have the points that come up in appraisals thoroughly discussed by engineers so that greater uniformity of practice will prevail.

Mr. William H. Bryan. — The author fully agrees with Mr. Moore that the word "value" is not the proper term when the transfer is a forced one, as when the city takes over the plant. The term, however, is applicable when the property passes from one private ownership to another, or where the appraisal is made for purposes of rate making or taxation. A clear statement of the method of appraisal, such as that cited by Mr. Moore, would materially assist the average investigation of this character.

Mr. Flad's views as to the impossibility of applying rigid rules strike the author as rather pessimistic. Some problems involving judgment and experience are, of course, involved,—the plant's condition and the probable life of each unit, for instance,—but even here the possibility of serious error is not great. With these assumptions intelligently made, the original cost, cost of duplication, depreciation and present physical value are readily determined with reasonable accuracy. If the assumptions of

probable life are sound, then such value must be somewhere near right. The only remaining factor, then, is the earnings. Will they justify a further allowance for "going" value, determined as stated in the paper, and a still further allowance for franchise value, or are they so small as not even to support the physical value? If so, even that figure must be reduced. Certainly something more logical and tangible than Mr. Flad's "generally accepted notion" as to the value should be insisted upon.

The author agrees with Mr. Flad as to the value of the sinking method of computing depreciation as a general proposition. The method, however, need not, and should not, give results materially at variance with the actual physical value at any intermediate date of appraisal. This he tried to show in the paper. In fact, due consideration of the purchaser's rights necessitates that he receive tangible value for his money, except, of course, where the earnings are large and may properly be considered.

Mr. Flad asks that the author give the detailed application of his arguments to the particular case cited. The figures as to costs, depreciation, sinking fund and present value are stated in the paper. The income was growing fast and had almost reached a point sufficient to pay all operating expense, including interest on present value and an increased sinking fund to cover further depreciation. No net earnings, therefore, existed. There was no demand for reduction of rates, nor were there any other features which affected the general situation. There had been considerable loss during the earlier years of the plant's operation, which, under the author's theory, would have justified some award for "going" value had the earnings warranted. No further consideration, however, could have been given to earnings, even had they existed, as the franchise was about to expire. The author's conclusion, therefore, was that, everything considered, the present actual physical value fairly represented the price at which the company should sell and the city purchase. This figure was accepted by both parties and is to be submitted to a vote of the people in the immediate future.

Mr. Flad's proposed water franchise is a laudable effort to improve existing conditions and to place such investments on a more secure and attractive foundation. The first two of his "principal assumptions" are unobjectionable. The third, however, as shown below, does not seem fair to the purchaser.

The practical application of Mr. Flad's plan will be found to involve some perplexities. It is proposed that the company be

allowed to earn a profit of 4 per cent. above all operating and fixed charges, earnings above that amount to be used for retiring bonds and making repairs, improvements and extensions. Manifestly such a fund could not be used for repairs, as they belong to operating expense. As the price which the city is eventually to pay for the plant includes only the face value of the bonds still outstanding, plus 10 per cent., the retirement of bonds and making of extensions inures wholly to the benefit of the city. The plan, therefore, returns to the city all profits above 4 per cent. In return for this, however, the city must, should it desire to purchase the plant, pay a 10 per cent. margin above the face value of the outstanding bonds as well as all unpaid nterest and dividends.

If the plant has not earned interest and dividends, the proposed method of including this shortage in the sale price would result in a high figure being placed on a losing venture. Conversely, where the profits had fully met these items, the selling price would be lower. In the first case, a high price is placed on an unprofitable plant, and in the second a lower price on a profitable plant, results manifestly inconsistent.

Mr. Flad places the 4 per cent. dividend on stock ahead of the sinking fund. This would seem unjustifiable. The keeping up of the plant is a legitimate and necessary item of expense — as much so as labor, fuel, repairs or interest. Therefore, the sinking fund item to cover depreciation must be earned before there can be any net profits available for paying dividends on stock.

Some lawyers would probably find objections to other provisions,— the fact that the stock represents no actual investment, but is allowed to earn 4 per cent., the duration of franchise; its exclusiveness, etc.,— but with these we are not concerned. Certainly such an enterprise is entitled to earn all operating, maintenance and fixed charges. In addition, owing to the uncertainties and risks necessarily attending the business, there should be no objection to a profit up to even 4 per cent., as Mr. Flad suggests. Difficulty will be found, however, in fixing the rates. The plant which Mr. Flad refers to would seem to suit a town of, say, about two thousand five hundred inhabitants. The original rates must be tentative and experimental. Some consideration must be given to rates in neighboring towns similarly situated, if immigration is to be encouraged, factories invited and the supplying of railroads solicited. Low rates are essential to do these things, to build up home consumption and

insure the abandonment of cisterns and wells. Profits come from large numbers of consumers at reasonable rates. To start out with high rates intended to cover all operating expense, fixed charges and 4 per cent. on the stock would be suicidal. Some losses in the earlier years of such plants are usually unavoidable.

The proposed method of purchase does not impress the author as altogether fair. If we assume that the plant has proved as profitable as anticipated, then the stockholders, having earned interest, fixed charges and the 4 per cent. on their stock, all water, have been well repaid. Why should they be given a further profit of 10 per cent.? Why is not every consideration of equity satisfied by repaying their actual investment and having them turn over the plant and the accrued sinking fund?

Suppose, however, that the plant has not been profitable. The purchase by the city being optional, it will consider no higher price than is justified by the earnings. If the company wants to unload and stop its losses, it will have to make a price to suit, regardless of all franchise conditions as to bond issues, profits on same, unpaid interest and dividends, etc.

There is another alternative, of course,—that of continuing the operation of the plant and of asking for a higher rate schedule.

As shown above, however, the possibilities in this direction are limited. Furthermore, higher rates might actually cause a reduction in net income, as causing some customers to go back to cisterns, wells or ponds.

The Illinois idea of readjustment of rates is intended to insure the capitalist a fair return on his investment, but it is equally applicable to prevent excessive profits. In such a case the city would probably demand and secure a lower rate schedule.

Incidentally it may be stated that the cost of duplicating the plant, or its present value, is usually considered more equitable as a basis of transfer than the total investment.

Mr. Russell's analysis is interesting and helpful. An increasing annual sinking fund might be desirable in many cases but there are advantages in uniform payments. The sinking fund plan is in effect an increasing payment on account of the interest earned.

Mr. Russell's suggestion that present values be determined by comparison with quotations on similar second-hand machinery in the open market has at least the merit of novelty. Like all

other methods, however, it will be found difficult of application. Aside from the improbability of finding apparatus of the same type, dimensions, age and condition, the selling price of second-hand machinery follows no known, or unknown, law. In some cases a machine has been so completely rebuilt as to command almost the price of a new machine, and in others, even if in good shape, it is hardly worth more than scrap. Immediate delivery sometimes adds to its selling value also. Even if a few sporadic cases could be found, they would not, in the author's judgment, compare in usefulness to the logical and well-digested use of the sinking fund plan.

The appraisal cited by Mr. Russell raises some important questions. No consideration seems to have been given the "going" value, independent of franchise or earning value. As already stated, there can, in the author's judgment, be no "going" value except when there are net earnings over and above interest and sinking fund charges. If there are such net earnings, then the author would award as "going" value a sum sufficient to cover the legitimate losses of the earlier years plus such sums as can be shown to have actually been spent in building up the business. And this "going" value inheres even when the franchise has expired. If the earnings are more than enough to pay fixed charges on physical plus "going" values, and if these earnings are reasonably sure to continue, then the author would estimate the amount of those earnings during the unexpired period of the franchise and reduce same to their present value. This he would call "franchise" value and add to the sum of the physical and "going" values to arrive at the total fair present value.

The author fears that any attempt to get a city to agree to share possible losses, even if it is also to have the right to share possible profits, is in advance of present-day ideas.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1908, for publication in a subsequent number of the JOURNAL.]

Association of Engineering Societies.

Vol. XXXIX. JULY, 1907. No. 1.

PROCEEDINGS.

Louisiana Engineering Society.

Synopsis of Work done in last Six Months.

The February issue of the Journal published the proceedings of the annual meeting of January 12, which was followed by the annual banquet held at the "Old Hickory."

The regular meeting for February 11 was not held on account of Mardi Gras Eve, at which time even engineers are prone to sacrifice engineering papers to carnival spirit.

The March meeting was held on the 11th of the month. Proposed changes in Constitution and By-laws were submitted for first reading. Mr. A. C. Duval read a very interesting paper entitled, "Remarks on the Flood of 1907," accompanied with two elaborate maps and a chart showing the crest of recent floods and maximum gage heights reached at various stations. An informal discussion followed by a number of the members.

The April meeting was held on the 8th. A proposed outing was suggested and decided upon, and the Outing Committee instructed to provide the ways and means. The formal discussion on "Remarks on the Flood of 1907" was then gone into. Mr. Lawes read his discussion, which proved very instructive. Both Mr. Duval's paper and the discussion by Mr. Lawes will shortly appear in the Journal. The second reading of proposed changes in the Constitution and By-laws followed. Exchange club-house and library privileges were arranged with the Montana Society of Engineers.

The meeting on May 13 was exceptionally well attended. The report of the Committee on Membership and Entertainment, submitted by Mr. S. F. Lewis, chairman, was read, showing that considerable progress had been made in obtaining new members. Mr. W. A. Haller read an interesting paper entitled "Modern Power House Construction," accompanied with numerous drawings and photographs. The Outing Committee, through its chairman, Mr. C. W. Wood, submitted its report, recommending a trip to Bogalusa, La., and the acceptance of a special train and service offered free of charge by the New Orleans Great Northern

R. R. Co., through Mr. J. F. Coleman, engineer. The question of new quarters for the society was taken up and a committee was ordered appointed to look into the matter and to report at the June meeting of the Society. Final action on proposed changes in Constitution and By-laws was taken and the recommendations of the committee adopted.

On June 8 the outing to Bogalusa, La., was taken and proved very enjoyable, the weather being fine and the affair considered a great success. About 150 members and guests had a pleasant and profitable day, visiting that thriving and "built to order" town where some of the greatest engineering work in the South is in progress. The special train pulled out of the N. O. Great Northern depot at 9 A.M. A string orchestra added to the occasion. A stop was made at the North Drawbridge, where Mr. J. C. Haugh, engineer of the N. O. & N. E. R. R. Co., explained the workings of the drawbridge. This bridge is one of two new bridges that were built recently to replace two old ones. They serve to break a six-mile span of trestle work across Lake Pontchartrain. This trestle work was formerly 22 miles long, but has from time to time been filled in, until but six miles remain.

The next stop was made at Slidell, La., where the party visited the Southern Creosoting Works, and saw the process of preparing lumber. A train of cars of untreated lumber was hauled into the huge cylinders, cars and all, and a train of treated lumber hauled out of another cylinder.

Upon arrival at Bogalusa the party went to the immense planing mill, in course of construction, where dinner was served, after which Mr. W. H. Sullivan, of the Great Southern Lumber Company, related some facts in connection with the establishment of the new town and the building of its immense industries. He described fully the big plant, told what had been done and what remained to be done; 600 000 acres of timber land to draw from, enough to keep the mill at full capacity for fifty years. The output will be 600 000 ft. a day, enough to construct from 30 to 40 houses. Fifteen hundred men are now employed in the construction of the mills. So far 18 000 000 ft. of lumber have been used in construction, together with 400 000 brick and 7 000 tons of steel.

Mr. Sullivan then noticed the surprised expressions of the Engineers and the "Missouri" look about them, so he proceeded to show them over the grounds, corroborated what he had said by pointing out the details of the immense undertaking and by explaining the various plants and their workings. After this interesting trip through the place the party returned to the starting point, and President Lawes moved a vote of thanks to Mr. N. G. Pearsoll, manager, and Mr. C. W. Goodyear, Jr., assistant manager of the N. O. Great Northern R. R.; to Mr. W. H. Sullivan, manager of Great Southern Lumber Company; to Mr. Armstrong, of the Southern Creosoting Works, and to Mr. J. C. Haugh, of the N. O. & N. E. R. R. Co., for their splendid entertainment, which helped to make the outing such a success. The train left Bogalusa at 5 P.M. and arrived in New Orleans at 7 with every one aboard enthusiastic over the results of the outing.

The regular meeting held June 10 was well attended. A proposition from Tulane University suggesting (1) that the Society abandon its present quarters and make Tulane University, opposite Audubon Park, its regular meeting place; (2) that the Engineering and University libraries be merged; (3) that the senior class men in the engineering courses at

Tulane be allowed to enter as junior members of the Society without paying the initiation fee; (4) that the Society pay $25 per month toward expenses of heat, light and library operation. The adoption of the above suggestions would have the following advantages: (1) The use of spacious Gibson Hall for meetings; (2) the Tulane Library will become available to members; (3) co-operation and help of engineering faculty.

It was decided to have a letter ballot of the members taken on the above proposition. Mr. W. A. Haller's paper on "Modern Power House Construction" was thoroughly discussed by several of the members and the discussion enjoyed by all. The next meeting of the Society will be in September, the Society voting to adjourn for the summer months of July and August. Appropriate resolutions of thanks to the officials in charge of various industries who entertained the Society on their Bogalusa outing were adopted.

The Secretary announced that the Board of Direction had ordered a letter ballot for 25 applicants to the several grades of membership in the Society.

L. C. Datz, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXIX. AUGUST, 1907. No. 2.

PROCEEDINGS.

Boston Society of Civil Engineers.

BOSTON, JUNE 19, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President E. W. Howe in the chair. Seventy-eight members and visitors present, including ladies.

The record of the last meeting was read and approved.

Messrs. John E. Carty, Ernest R. Kimball, Edward F. Murphy, William F. Mahoney and Henry T. Stiff were elected members of the Society and Mr. John B. Graham an associate of the Society.

The literary exercises were furnished by Mr. Desmond FitzGerald, past president of the Society, who exhibited and described a large number of very beautiful colored lantern slides made from photographs taken by him in his travels in various parts of the world.

Adjourned.

S. E. TINKHAM, *Secretary*.

Association of Engineering Societies.

Vol. XXXIX.	SEPTEMBER, 1907.	No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, June 5, 1907. — The 636th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, June 5, 1907, at 8.15 o'clock. President Fish presided. Forty-five members and twenty-four visitors were present.

The minutes of the 635th meeting were read and approved.

The following applications were presented: Forest Shepard Lyman, member; Guy Carleton Pierce, associate member.

The following were elected: William B. Ittner, member; Henry Craig Morrison, junior; Hans Schantl, member; Ernest Osgood Sweetser, member.

Mr. West, on behalf of the Western Society of Engineers, extended a very cordial invitation to the Engineers' Club of St. Louis to visit points of engineering interest in and about Chicago. Upon motion of Professor Langsdorf a vote of thanks was extended to the Western Society of Engineers and to their representative, Mr. West, for the courteous invitation.

It was moved by Mr. Toensfeldt that the matter of the date of the proposed trip be referred to the Entertainment Committee. Motion carried.

The paper of the evening, upon the "Present Status of the Producer-Gas Plant in the United States," was presented by Mr. R. H. Fernald. The paper was illustrated by a liberal supply of lantern slides and touched upon the following points:

1. Rapid development of the gas engine.
2. Development of the gas-producer.
3. Tests of the United States Geological Survey.
4. Relative results of steam and producer-gas tests.
5. Views of the manufacturer.
6. Situation to-day regarding various difficulties.
7. Cost of producer-gas installations.
8. Estimated operating costs of producer-gas plants.
9. Views of owners and operators of producer-gas plants.
10. Centralization of power development and distribution.

Written discussion was presented by Mr. M. L. Holman, and oral discussion was participated in by Messrs. Russell, Bryan, E. C. Parker, Richard Phillips, Robert Moore, Palmer, Layman, and Fernald.

Adjourned.

R. H. Fernald, *Secretary.*

Association of Engineering Societies.

Vol. XXXIX. OCTOBER, 1907. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, September 18, 1907. — The 637th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, September 18, 1907, at 8.15 o'clock. President Fish presided. Thirty-five members and twenty-six visitors were present. The meeting was an open one, and a large number of ladies were among the visitors.

The minutes of the 636th meeting were read and approved. The minutes of the 425th and 426th meetings of the Executive Committee were read.

The records of the trip to Chicago, July 26 and 27, as guests of the Western Society of Engineers, and of the dinner given on July 3 in honor of visiting members and guests of the American Society of Civil Engineers, were read.

The following applications were presented: Henri Rusch (member); Burkett Sale Clayton (member); Lawrence Rudolph Ebert (member); Theodore Barnes Entz (member); Elbridge B. Fulks (member); Henry England Grimm (member); Alfred Lewis Kammerer (member); Edward M. Kurtz (member); William M. Penniman (member); Ejnar Posselt (member); Charles William Sylverius Sammelman (member).

The following were elected: Forest Shepard Lyman (member); Guy Carleton Pierce (associate member, non-resident).

The President called for nominations for the secretaryship, made vacant by the resignation of Prof. R. H. Fernald. Mr. R. S. Colnon nominated Mr. A. S. Langsdorf. Moved by Mr. Richard McCulloch, and duly seconded, that nominations be closed. Motion carried. Moved and carried that the President cast the ballot of the meeting in favor of Mr. Langsdorf. The President thereupon declared the ballot cast and Mr. Langsdorf duly elected.

The paper of the evening upon " A Trip to Egypt " was presented by Mr. Richard McCulloch. The address was illustrated by a large number of lantern slides.

On motion of Mr. Rohwer it was voted to extend the thanks of the Club to Prof. R. H. Fernald for his past services as Secretary.

The members and visitors then adjourned to the reception rooms of the Club, where refreshments were served.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, October 2, 1907. — The 638th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, October 2, 1907, at 8.15 o'clock. President Fish presided. There were also present twenty-one members and three visitors.

The minutes of the 637th meeting were read and, with a slight correction in the spelling of the name of a candidate for membership, were approved. The minutes of the 427th and 428th meetings of the Executive Committee were read.

The following were elected to full membership: Henri Rusch, Burkett Sale Clayton, Lawrence Rudolph Ebert, Theodore Barnes Entz, Elbridge B. Fulks, Henry England Grimm, Alfred Lewis Kammerer, Edward M. Kurtz, William M. Penniman, Ejnar Posselt, Charles William Sylverius Sammelman.

Applications were read from the following: William S. Dawley, member; Paul A. Fusz (member); Samuel Kauffman (member); John M. Monie (member).

Mr. H. Rohwer, in a written communication, submitted the following resolution:

" In accepting the resignation of Prof. R. H. Fernald as Secretary of the Engineers' Club of St. Louis, the latter, in due recognition of the untiring effort in promoting the welfare of this Club and services rendered, have

"*Resolved*, That the Engineers' Club of St. Louis extend to said Prof. R. H. Fernald its thanks for said labor so performed by him in the interest of this Club; and be it further

"*Resolved*, That the Secretary be instructed to enter this on the books of the Club and furnish said Prof. R. H. Fernald with a copy of same."

On motion, duly seconded, the above resolution was unanimously carried.

The President announced the receipt of a framed photograph, taken on the occasion of the visit of the Club to Chicago, July 26 and 27; the Secretary was instructed to make proper acknowledgment of the same.

The President announced that the expenditure on the occasion of the visit of members and guests of the American Society of Civil Engineers, on July 3, had amounted to $194.10; and that this expenditure, being in excess of the limit prescribed by the by-laws, required the approval of the Club. It was moved by Mr. Layman, and seconded by Mr. Bryan, that the expenditure be approved. Motion carried.

Mr. Richard L. Humphrey read the paper of the evening on " The Work of the Structural Materials Testing Laboratories." The paper was illustrated by a large number of lantern slides, showing details of many of the tests.

An active discussion of the paper was participated in by Messrs. Greensfelder, Bryan, Van Ornum, Toensfeldt, Harting, Fish and R. L. Humphrey.

A motion to extend a vote of thanks to Mr. Humphrey for presenting this paper was unanimously carried.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, SEPTEMBER 18, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President E. W. Howe in the chair. Ninety-one members and visitors present, including ladies.

The record of the last meeting was read and approved.

Mr. John M. Shea was elected a member of the Society.

The President announced the death of Alfred E. Nichols, a member of the Society, who died July 31, 1907, and on motion the President was requested to appoint a committee to prepare a memoir. The President has appointed as that committee Messrs. George A. Nelson and Arthur T. Safford.

Mr. Desmond FitzGerald, for the committee appointed to prepare a memoir of Charles H. Haswell, an honorary member of the Society, presented and read its report.

The Secretary read, in the absence of either member of the committee, a memoir of Frank W. Upham, a member of the Society, prepared by Messrs. Irving T. Farnham and Rowland H. Barnes.

On motion of the Secretary, the thanks of the Society were voted to Mr. John J. Leahy, superintendent of sewers of Boston, for his courtesy in placing the city boat *Cormorant* at the disposal of the Society on the occasion of the excursion down the harbor on August 22.

The thanks of the Society were also voted to Simpson Brothers Corporation for courtesies shown to members this afternoon at the inspection of the Hassam pavement in Cambridge.

Mr. Herman K. Higgins then gave a very interesting informal talk entitled, "Panama from the Human Side." A large number of lantern slides were thrown on the screen, showing not only the work now under way for the excavation of the canal, but the life and scenery at the isthmus.

Mr. F. P. Stearns, with the aid of diagrams, showed the progress that had been made month by month in the amount of material excavated from the canal.

Adjourned.

S. E. TINKHAM, *Secretary.*

Montana Society of Engineers.

BUTTE, MONT., SEPTEMBER 14, 1907. — The meeting of the Society for September, 1907, was held at 225 North Main Street, Room No. 16, at the usual hour. On the arrival of a quorum, Trustee McArthur was selected to preside. The minutes of the May meeting were read and approved. Applications for membership of Messrs. Algie, Kenrick, Eckles, Lincoln, Simons and Schiertz were read, and on approval ballots were ordered. Messrs. N. L. Leonard, Putnam, A. N. Winchell and McCormick by request were placed in the Corresponding Member Class. The chair appointed the following Committee on Nomination of Officers for the coming year: Messrs. Charles W. Goodale, E. W. King and John D. Pope. A communication from President Kinney was read and action thereon postponed till some subsequent meeting.

Adjournment.

CLINTON H. MOORE, *Secretary.*

―

Association

of

Engineering Societies.

Vol. XXXIX. NOVEMBER, 1907. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 16, 1907. — The 639th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, October 16, 1907, at 8.15 o'clock. Vice-President Brennekc presided. There were present thirty-five members and seven visitors.

The minutes of the 638th meeting were read and approved.

Applications for membership from the following-named gentlemen were read: Morton Lewis Byers, William H. Schewe.

The following were elected: Willam S. Dawley (member), Paul A. Fusz (member), John M. Monie (member).

The Secretary read a letter from the Reinforced Concrete Construction Company containing an invitation to the members of the Club to be present at certain tests to be made at Washington University on Friday morning, October 18.

The address of the evening, on "Some Recent Observations of European Railroads," by Mr. Albert T. Perkins, of the Municipal Bridge and Terminal Commission, was then presented. Mr. Perkins spoke informally of his experiences and observations during the summer of 1907 on many of the railroads of Germany, France and England, and illustrated his remarks with numerous slides, showing typical features of track construction, rolling stock and terminal facilities in those countries. In the course of his address Mr. Perkins answered numerous questions asked by members present.

At the conclusion of the address a unanimous vote of thanks was tendered Mr. Perkins for his kindness in thus addressing the Club.

Adjourned.

A. S. Langsdorf, *Secretary.*

Civil Engineers' Club of Cleveland.

Regular Meeting, June 11, 1907, at the Club rooms, called to order at 8 o'clock p.m. by the President. Present: 25 members, 2 visitors.

Minutes, preceding meeting, read and approved.

The tellers, Messrs. Lane and Hanford, reported the election to active membership of Messrs. James Stewart, Eugene R. Woodruff, C. McD.

Townsend, George H. Lapham, Myron B. Vorce, William S. Lougee, Malcolm Hard, William A. Rowe, Gay E. Randall.

The paper of the evening, " The Intake Tunnel and River Shaft of the Detroit Water Works," was read by Mr. James Ritchie.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

REGULAR MEETING, October 8, 1907, at the Club Rooms, called to order at 8.15 P.M. by Vice-President Beahan. Present: 29 members and 2 visitors.

Minutes, preceding meeting, read and approved.

Applications for active membership from the following, approved by the Executive Board, were read: Everett L. Brown, R. Walker Henderson, John P. Iltis, Arthur F. Kwis, Thomas G. Mouat, Paul S. Schmidt, Andrew J. Wenzell, and for transfer from the Montana Society of Horace D. McLeod.

A proposal to confer Honorary Membership upon Mr. William H. Searles, signed by five active members of the Club, was read by the Secretary and referred to the Executive Board.

Mr. William A. Rowe read the paper of the evening, " The Buffalo Air Washer and Humidifier and Some of its Applications to Industrial Purposes."

Luncheon was served after adjournment.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., OCTOBER 16, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President E. W. Howe in the chair; 72 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Ralph W. Loud, Robert A. Vespers and Frederic J. Wood were elected members of the Society.

The President then introduced Mr. Edward W. DeKnight, of New York, manager of the Hydrex Felt and Engineering Company, who read a paper entitled, " Waterproof Engineering." The paper was illustrated by lantern slides.

A general discussion followed on the waterproofing of concrete and on the necessity of protecting steel embedded in concrete, in which Mr. C. T. Purdy, of New York, and a number of members of the Society took part.

On motion of Mr. Larned, the thanks of the Society were voted to Mr. DeKnight for the very interesting paper which he had read.

Adjourned.

S. E. TINKHAM, *Secretary.*

Montana Society of Engineers.

BUTTE, MONT., OCTOBER 12, 1907. — The monthly meeting of the Society for October, 1907, was held at 225 North Main Street, at 8 P.M. Vice-President Arthur H. Wethey presided. Minutes of the last meeting approved as read. Messrs. Algie, Eckles, Kenrick, Lincoln, Schiertz and Simons were elected active members of the Society. The Secretary read an invitation to the Society to hold its next annual meeting at Bozeman, Mont., from the Gallatin Valley Commercial Club. Action deferred.

Adjournment.

CLINTON H. MOORE, *Secretary.*

Detroit Engineering Society.

DETROIT, MICH., OCTOBER 25, 1907.—The 103d meeting of the Detroit Engineering Society was held in the Employers' Association Hall, Stevens Building, on Friday evening, October 25, 1907, at 8.15 o'clock. President Wheeler presided. Seventy members present.

The minutes of the 102d meeting were read and approved.

The following names were balloted upon and elected: Harlow N. Davock and Waldemar C. Keotz.

The report of the Memorial Committee on the death of William Joshua Phelps was read by Mr. Fales, as follows:

IN MEMORIAM.
WILLIAM JOSHUA PHELPS,
Member of Detroit Engineering Society.

The death, on September 3, of Mr. Phelps took out of the world and the profession an earnest man and an accomplished engineer, one who had done something to make life better for all men, and who had made the debt which the world owes to engineers greater.

He was born in Elmwood, Ill., on November 19, 1866; received his collegiate training at Knox. Among Greeks he was a member of the Phi Delta Theta fraternity. In addition to the Detroit Engineering Society, he held membership in the American Institute of Electrical Engineers, the Society of Illuminating Engineers and the American Society for the Advancement of Science.

In the business world he was vice-president of the Phelps Company, and manufactured the "Hylo" lamp, which he invented.

He is credited with being the originator of the turn-down lamp, and the inventor of the motorless flasher, so extensively used in electrical advertising.

In the blaze and brilliance of the myriad twinkling lights which give to our city streets by night the fascination of avenues of romance and legend, his genius still lives and flashes.

It is a pity that a man so richly endowed should leave the world when the potentialities of life were still in the ascendant.

He seemed in a fair way to recover after a radical mastoid operation at the Grace Hospital, but inflammation set in and after a few unconscious days death ensued. His widow, two children, father, mother, brother and sister, survive him.

The final resting place is at Springdale Cemetery, Peoria, Ill.

Signed, F. C. SHENEHON,
BINGLEY R. FALES,
Committee.

Moved by Mr. Fales, supported by Mr. Kales, that the report as read be adopted and published in the Association Journal, and copies sent to members of the family. Carried.

The paper of the evening, upon "Some Recent Experiments in the University of Michigan Ship Model Tank," was presented by Dr. Herbert C. Sadler.

Oral discussion by Mattsson, Shenehon, Lane, Russel, Pessano, etc.

Moved and supported that Dr. Sadler be given a vote of thanks. Carried.

Moved and supported that we adjourn. Carried.

Bamlet Kent, *Secretary.*

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Vol. XXXIX.	DECEMBER, 1907.	No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, November 6, 1907. — The 640th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, November 6, 1907, at 8.15 o'clock. President Fish presided. There were present thirty-eight members and twelve visitors.

The minutes of the 639th meeting were read and approved. The minutes of the 430th meeting of the Executive Committee were read.

The following were elected: Morton Lewis Byers (member), Samuel Kauffman (member), William H. Schewe (member).

Applications were presented from the following: Julius Lilien Jacobs (member), Franklin Dew Hudgins (member), Albert T. Perkins (associate member), Preston Allen Richardson (junior).

This being the first regular meeting in November, the chairman announced that, according to the By-Laws, the election of a Nominating Committee of five members was in order, and nominations for this committee were called for. The following were nominated: E. B. Fay, A. O. Cunningham, S. B. Russell, C. A. Moreno, R. H. Phillips, R. Morey, Wm. A. Baehr, R. S. Colnon.

The result of the ballot was as follows:

R. S. Colnon	33
E. B. Fay	33
C. A. Moreno	28
A. O. Cunningham	23
W. A. Baehr	21
R. H. Phillips	21
R. Morey	11
S. B. Russell	10

Messrs. Baehr and Phillips having tied for fifth place, a new ballot was called for, which resulted: R. H. Phillips, 18; W. A. Baehr, 17.

The committee was therefore declared constituted as follows: R. S. Colnon, E. B. Fay, C. A. Moreno, A. O. Cunningham, R. H. Phillips.

Mr. Wm. H. Bryan presented the paper of the evening on "The Appraisal of Water Works and Similar Properties." The paper treated in detail of the various possible methods of estimating the value of such properties with regard to such items as depreciation, "going value," etc.

The paper was discussed at considerable length by Messrs. Robert Moore, Edward Flad, S. Bent Russell, J. R. Cullinane, R. H. Phillips and W. H. Bryan.

The meeting adjourned at 10.40 P.M.

A. S. Langsdorf, *Secretary*.

St. Louis, November 20, 1907. — The 641st meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, November 20, 1907, at 8.15 o'clock, Mr. Richard McCulloch presiding. There were present about fifty members and visitors.

The minutes of the 640th meeting were read and approved.

The Secretary read a letter from the Reinforced-Concrete Construction Company in which an invitation was extended to the members of the Club to be present at a series of tests on imbedded steel bars and bent bars to be made at the Testing Laboratory of Washington University on November 26, 27, 29 and 30; these tests completing the bonding tests decided upon by the Board of Appeals on July 15, 1907.

The Secretary also read a letter from Mr. Richard L. Humphrey, of the Structural Materials Testing Laboratories, asking for the postponement of the proposed visit of inspection until some future date, to be mutually agreed upon.

The Chairman announced that the next meeting of the Club, on December 4, would be the Annual Meeting.

The following were elected: Julius Lilien Jacobs (member); Franklin Dew Hudgins (member); Albert T. Perkins (associate member); Preston Allen Richardson (junior).

The Nominating Committee presented the following report:

November 20, 1907.

To The Engineers' Club of St. Louis,
St. Louis, Mo.

Gentlemen, — Your Nominating Committee submits herewith the names of the candidates selected for the various offices for the ensuing year.

President — Mr. W. G. Brenneke.
Vice-President — Mr. E. E. Wall.
Secretary and Librarian — Mr. A. S. Langsdorf.
Treasurer — Mr. O. F. Harting.
Directors — Mr. J. F. Hinckley, Mr. W. V. N. Powelson.
Members of the Board of Managers, Association of Engineering Societies — Mr. R. L. Murphy, Mr. O. W. Childs.

Respectfully submitted,
(Signed) R. S. Colnon, *Chairman,*
E. B. Fay,
C. A. Moreno,
A. O. Cunningham,
R. H. Phillips.

The Chairman announced that Mr. Charles F. Müller had died on November 14, 1907.

The paper of the evening on "The New Plant of the Wagner Electric Manufacturing Company" was then presented by Messrs. W. A. Layman and E. B. Fay. Mr. Layman presented the general features of the plant and the policy of the company in planning and constructing the buildings. He stated that five months' occupancy had shown the arrangement to be exceedingly satisfactory and that were the project to be undertaken again, the same plans would be adopted. Mr. E. B. Fay then described the technical features of the design and construction of the buildings, illustrating his statements by numerous lantern slides. Mr. A. H. Timmerman then presented some details of the construction and operation of the power house of the company.

A lively discussion of the paper was participated in by Messrs. W. H. Bryan, Richard McCulloch, Edward Flad, R. H. Phillips, H. H. Humphrey, E. B. Fay, H. C. Toensfeldt, W. Robbins, S. Trepp and A. S. Langsdorf.

In the course of his remarks, Mr. Layman extended an invitation to the members of the Club to visit the plant of the Wagner Company, at a time to be fixed by the officers of the company and the Entertainment Committee of the Club.

Adjourned.

A. S. Langsdorf, *Secretary.*

The Civil Engineers' Club of Cleveland.

Regular Meeting, November 12, 1907, at the Club rooms, called to order by the President at 8 p.m.; present: about 60 members and 25 visitors.

Minutes, preceding meeting, read and approved.

The tellers, Messrs. Horner and Herman, reported the election to active membership of Messrs. Everett L. Brown, R. Walker Henderson, John P. Iltis, Arthur F. Kwis, Thomas G. Mouat, Paul S. Schmidt, Andrew J. Wenzell and for transfer from the Montana Society, Howard D. McLeod.

The same tellers also reported the election to honorary membership of Mr. William H. Searles.

The Secretary read extracts from the minutes of the meeting of the Executive Board, on November 5 last, relating to reports made to the Board: in favor of tendering honorary membership to Professor Benjamin, lately resigned as a member of the Club; to various reports of the Publication Committee, and to a report from the Library Committee relative to a propositon from Case Library for the resuming of former relations subsisting between the Club and the Library, with some important modifications of the former arrangement.

The Secretary, as chairman of a special committee of the Executive Board, with power to report directly to the Club, read the proposition from Case Library and reported that the committee were unanimously in favor of accepting the proposition.

On motion of Mr. Herman the report was received and discussion was deferred until after the reading of the paper of the evening.

Prof. R. H. Fernald, of Case School, then read the paper of the evening, "Producer-Gas Power Plants," illustrated with many lantern slides.

Mr. Swasey followed with remarks eulogizing the work of Professor Fernald along these lines. On motion of a member, a vote of thanks was tendered Professor Fernald.

Discussion of the report of the special Library Committee of the Executive Board followed. On motion of Mr. Osborn, the Secretary was directed to have the proposition of Case Library printed and mailed to the members of the Club for discussion at the December meeting.

On motion of Dr. Howe, the President was requested to appoint a special committee to examine further into the proposition and report to the Club at the December meeting if possible. The President named the following as this committee: Beardsley, Osborn, Herman, Miller and Fuller.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Boston Society of Civil Engineers.

Boston, November 20, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8.10 o'clock P.M.; President E. W. Howe in the chair; thirty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. Julius W. Bugbee and Joseph H. O'Brien were elected members of the Society.

On motion of the Secretary, the thanks of the Society were voted to Admiral Francis T. Bowles, president of the Fore River Ship Building Company, and to his assistant, Mr. J. J. Crain, for courtesies extended to the Society on the occasion of the excursion to the works of that company at Quincy Point, on November 15, 1907.

In the absence of the author, Mr. Stephen Child, the Secretary then read the paper of the evening, entitled, "Civic Centers and the Grouping of Public Buildings, with Suggestions for Boston." The paper was fully illustrated by lantern slides.

Mr. C. Howard Walker, in response to an invitation of the President, spoke of the many admirable opportunities in Boston for the grouping of public buildings, and of the efforts which had been made by the architects to awaken public interest in the matter.

Mr. Sylvester Baxter, secretary of the Metropolitan Improvements Commission, was also introduced and spoke entertainingly of the development of the plan of the late Charles Eliot for the improvement of the Metropolitan district. He also gave an account of the work of the Metropolitan Improvements Commission.

After passing a vote of thanks to Messrs. Walker and Baxter for their discussion of the subject-matter of the evening, the Society adjourned.

S. E. Tinkham, *Secretary.*

Boston, December 18, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., Vice-President Francis W. Dean in the chair; thirty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. William L. Church, Charles C. Doten and Frank M. Gunby were elected members of the Society.

On motion of Mr. F. L. Fuller, the thanks of the Society were voted to Mr. F. H. Keys, general manager of the Robb-Mumford Company, and to Messrs. H. L. Egan and Richard H. Long, for courtesies extended to members of the Society on the occasion of the visit to the boiler shops of the Robb-Mumford Company, and to the new shoe shops of Richard H. Long, at South Framingham, this afternoon.

The Chairman then introduced Mr. W. M. Davis, of Boston, who read a paper entitled, " Economical Lubrication in Large Plants."

The paper was discussed by the Chairman and Messrs. Francis H. Boyer, Ira N. Hollis and Irving E. Moultrop.

The second paper of the evening was presented by Mr. E. G. Bailey, of Boston, entitled, " Furnace Design in Relation to Fuel Economy."

Owing to the lateness of the hour it was voted to continue the discussion of both papers at a meeting to be called after they had been placed in type and distributed to members interested in the subjects.

After passing a vote of thanks to Messrs. Davis and Bailey for their interesting papers which they had presented, the Society adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

A special meeting of the Sanitary Section was held at the Copley Square Hotel, Wednesday evening, May 1, 1907, thirty-eight members being present.

There was a general discussion on the subject of run-off from sewered areas, the methods adopted for securing data and the results accomplished. The discussion was participated in by Messrs. L. M. Hastings, I. T. Farnham, J. H. Kimball, G. A. Carpenter, Leonard Metcalf, R. A. Hale, H. K. Barrows, E. S. Dorr, J. L. Howard and others. Apparatus in use for determining the flow in storm sewers and for recording the intensity of rainfall was described by several of the speakers, and the importance of obtaining accurate data was emphasized by all.

At the conclusion of the discussion, on motion made by Mr. George A. Carpenter, it was voted that a committee of five be appointed by the chair to consider methods for obtaining reliable facts in regard to rainfall and run-off, to endeavor to interest city officials and others in installing apparatus for this purpose and to collect and collate such records as may be obtained.

The Chairman has appointed as members of this committee Messrs. Irving T. Farnham, Lewis M. Hastings, Hector J. Hughes, George A. Carpenter and Harrison P. Eddy.

William S. Johnson, *Clerk.*

A meeting of the Sanitary Section was held at the Boston City Club, Friday evening, November 15, 1907, with sixty-one members present. Prof. C.-E. A. Winslow and Prof. E. B. Phelps read a paper entitled, " Purification of Boston Sewage — Experimental Results and Practical Possibilities." The paper was discussed by Prof. W. T. Sedgwick, Mr. X. H. Goodnough and others. The attendance at the dinner which preceded the meeting was forty-four.

William S. Johnson, *Clerk.*

A meeting of the Sanitary Section was held at the Boston City Club, Wednesday evening, December 4, 1907. Mr. Charles F. Choate, Jr., addressed the Section upon the " Pollution of Waters at Common Law and Under Statutes." The attendance was forty-five.

William S. Johnson, *Clerk.*

Montana Society of Engineers.

Butte, Montana, November 9, 1907. — The regular meeting of the Society for November, 1907, was held at the usual hour, 8 p.m., in the Society Room, 225 North Main Street. Quorum present. Charles H. Bowman was chosen to preside. The minutes of the last meeting were

read and approved. The Committee on Nomination of Officers for next year presented the following names, and the Secretary was instructed to circulate ballots for the same.

President — Archer E. Wheeler, Great Falls.
First Vice-President — Charles H. Bowman, Butte.
Second Vice-President — Frank M. Smith, East Helena.
Secretary and Librarian — Clinton H. Moore, Butte.
Treasurer and Member of Board of Managers of Engineering Societies — Samuel Barker, Jr., Butte.
Trustee — John C. Adams, Butte.

By a vote of the Society, Bozeman, Montana, was chosen as the place for holding the next Annual Meeting of the Society, January 9, 10, 11, 1908. The Secretary was instructed to request President Edward C. Kinney to appoint an Entertaining Committee, and he has made the following selection: Ernest W. King, Clayton M. Thorpe, George M. Lewis.

Mr. John D. Pope was chosen to present the draft of an amendment to the By-Laws. A communication from Mr. Thomas E. Lambert was read by the Secretary.

Adjournment.

Clinton H. Moore, *Secretary.*

Detroit Engineering Society.

Special Meeting, November 26, 1907, Stevens Building. — Mr. Axel Welin, A. I. N. A., Mechanical Engineer, London, England, was introduced by First Vice-President Mattsson, at 8.15 p.m., who presented a paper entitled, "Appliances for Manipulating Lifeboats on Seagoing Vessels."

Discussion followed, by Mr. William Livingstone and Mr. Mattsson, etc.

F. C. Shenehon, *Acting Secretary.*

Detroit, Mich., November 29, 1907. — The 104th meeting of the Detroit Engineering Society was held in the Employers' Association Hall, Stevens Building, on Friday, November 29, 1907, at 8.10 p.m. Vice-President Mattsson presided.

The minutes of 103d meeting were read and approved.

The following names were balloted upon and elected: Wm. H. Dorrance, Geo. L. Grimes, Guy P. Henery, M. S. MacDiarmid and Ira C. Sunderland.

The paper of the evening upon " The Transmission of Heat through Iron Radiators " was presented by Prof. John R. Allen of the University of Michigan.

Oral discussion followed by Weil, Fales, Dunlop, Van Tuyl, Brush, Shenehon, Parke, Allen, etc.

Moved by Mr. Weil that a vote of thanks be given Professor Allen, and that he be requested to prepare his paper for publication in the Association Journal. Carried.

Adjourned, 10.25 p.m.

F. C. Shenehon, *Acting Secretary.*